Dolmatz and Wong

PHYSICAL SCIENCE

# Teachers Manual

IDEAS AND INVESTIGATIONS IN SCIENCE

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# PHYSICAL SCIENCE

## IDEAS AND INVESTIGATIONS IN SCIENCE

# Teachers Manual

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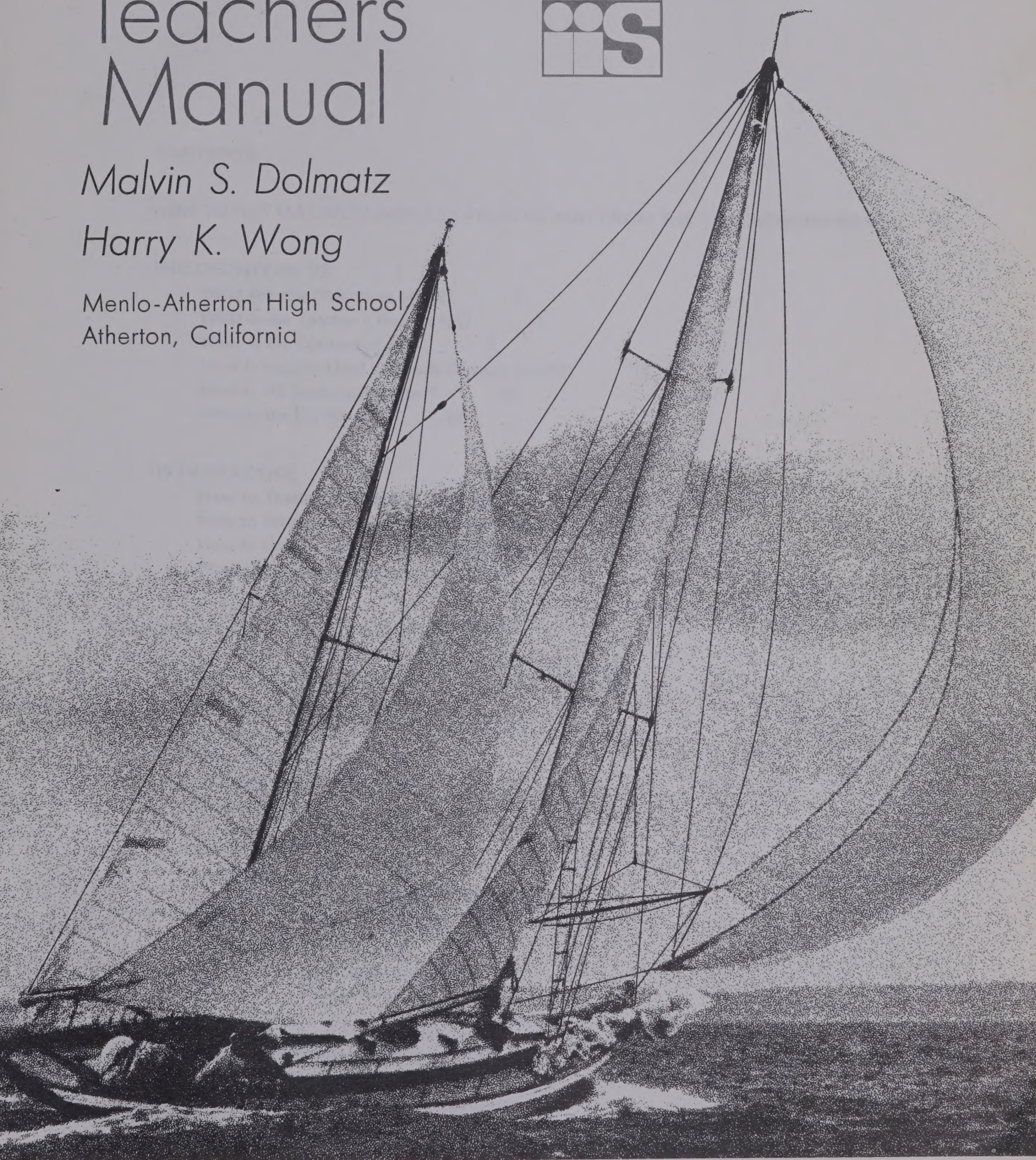

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*Dedicated to the students of Menlo-Atherton High School*

TEACHERS MANUAL
Ideas and Investigations in Science–PHYSICAL SCIENCE
Malvin S. Dolmatz *and* Harry K. Wong



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CONTENTS

## HOW TO GET MAXIMUM RESULTS FROM IIS AND FROM THE TEACHERS MANUAL

You're a teacher and this book is written for you—to give you all the help possible so that both you and the student may be successful with IIS.

1. Know your audience. IIS is for the disinterested student who requires a special approach. See "What Is the Teacher's Role in IIS?" (page 1).

2. Know how IIS is organized. See "What Is the Content of IIS?" (page 3).

3. Explain the course to the students. Tell them that they will be learning a set of concepts as they work through a series of investigations. See "How Is Inquiry Used to Teach Content in IIS?" (page 14).

4. Make science socially relevant by using the opportunities provided in many of the investigations. See "How Is IIS Socially Relevant?" (page 16).

5. Read "How to Teach the Program" (page 18) and "How to Prepare Each Laboratory Investigation" (page 20), and note how the guide for each investigation is organized (page 20).

6. Use assistants or aides to help you set up each investigation.

7. Order all your supplies early. A master supply list for Physical Science is on page 177.

## PHILOSOPHY OF IIS

### What Are the Objectives of IIS?

Each year over two million high school students enroll in some kind of general science course. This enrollment is greater than that in any of the college preparatory science courses such as biology (only 1.85 million), chemistry, and physics.

These students are the largest segment of our high school population—the non-college-bound, average, science-shy students. They are future housewives, sales-ladies, secretaries, mechanics, bus drivers, and laborers. They are of average and perhaps below-average intelligence, and some day they will form the heart and backbone of American society. Yet these students have been neglected in most of our curriculum reform programs.

The challenge of these students motivated the authors to initiate a project in 1964, the purpose of which was to develop a science program for the student who may

a. come from an economically disadvantaged environment, which has caused him to fall behind in school.

b. be uninterested in traditional school activities.

c. come from a minority cultural background.

d. find it difficult to learn from traditional methods, such as lectures and books.

The materials developed by the authors were tested and revised annually for four years before they were tested nationally by a panel of 29 pilot teachers in nine urban centers under the sponsorship of Prentice-Hall, Inc. The resulting program, called *Ideas and Investigations in Science* (IIS), has the following objectives:

1. To use the major conceptual themes as the content framework.

2. To derive a sequence of concepts from a series of laboratory investigations.

3. To involve the student in the processes of science as he uncovers each concept in the laboratory.

4. To make possible continued success for the student.

5. To make scientific problems with social implications an integral and relevant part of as many lessons as possible.

6. To use examples familiar to the urban and non-white student.

### What Is the Teacher's Role in IIS?

Educators have long recognized that any successful program must be student-centered. IIS has been designed with the student at the center of the program. Students spend most of each IIS day working on an investigation, either personally or with a partner, or involved in a class discussion.

The teacher's role in such a program is unique and requires a special orientation.

1. An IIS teacher should be one of the more experienced teachers who has an understanding of the new generation of science programs; for example, BSCS, CHEMS, and IPS. The IIS program is strongly process-oriented and should be taught by a teacher who recognizes the value of teaching process and content simultaneously.

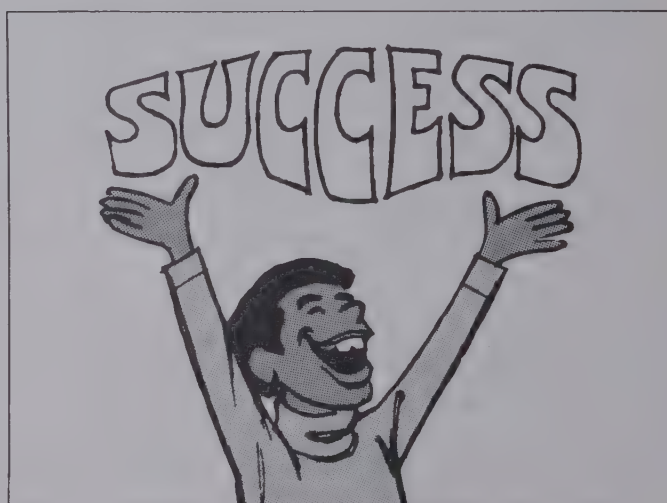
2. An IIS teacher should have enough confidence in his teaching ability to refrain from lecturing. Students must be allowed to become the active agents in the educational process.


3. An IIS teacher should become involved with the students. The IIS program is centered around teacher-guided inquiry, not unassisted discovery.

4. An IIS teacher should react to the students' need for approval and affection. A constant smile, a warm but firm hand, and a genuine concern will usually break down any facade of belligerence thrown up by the student.


5. An IIS teacher must never exhibit cynicism. Many uninvolved students have a strong feeling of fatalism, helplessness, dependence, and inferiority in social and academic situations. The IIS teacher should frequently praise his students.


6. An IIS teacher should assist the students to achieve success. There is *nothing* to be gained by failing students. Success can be enhanced by reading the investigations together as a class, discussing class data, and coming to a conclusion based on class agreement.



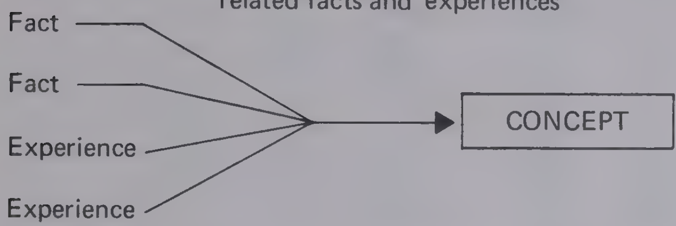

7. An IIS teacher should be given the best laboratory, schedule, and equipment possible. The uninvolved student should not be given substandard laboratories and inadequate equipment.

8. An IIS teacher should teach science with a focus on values. He should give meaning to science and its influence on the material, social, and intellectual life of our time.

## What Is the Content of IIS?

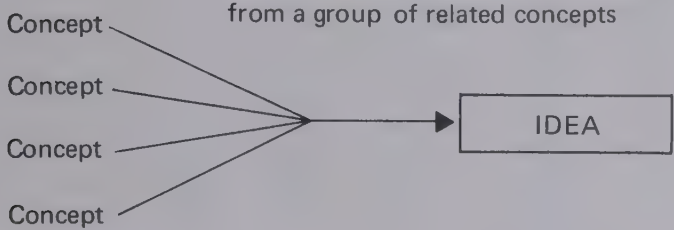
The IIS program develops concepts and ideas in a vertical manner. There are 108 investigations, organized into ten major Ideas. Each investigation consists of a set of related facts and experiences from which the student derives a concept.

A concept is formed from a group of related facts and experiences




A series of 9 to 12 related concepts builds up to each Idea, which can be pictured as a sequence of related concepts developed in a vertical manner.

An idea, or generalization, is formed from a group of related concepts




The horizontal structure of the IIS program is based on the Ideas, which represent one view of the conceptual framework of science. There are five Ideas in the biological sciences and five in the physical sciences.

Physical Science Idea 1, *Predicting:* Science is an attitude, a method, an activity of man interested in finding out more about his natural environment.

Physical Science Idea 2, *Matter:* The universe is composed of matter and all matter is made of tiny particles.

Physical Science Idea 3, *Energy:* When particles of matter interact, energy may be either released or absorbed.

Physical Science Idea 4, *Interaction:* Matter and energy are constantly interacting, producing our changing environment.

Physical Science Idea 5, *Technology:* Man's understanding of the interactions of matter and energy allows him to control his environment.

Biology Idea 1, *Inquiry:* Science is an activity, a way in which man discovers more about his natural world.

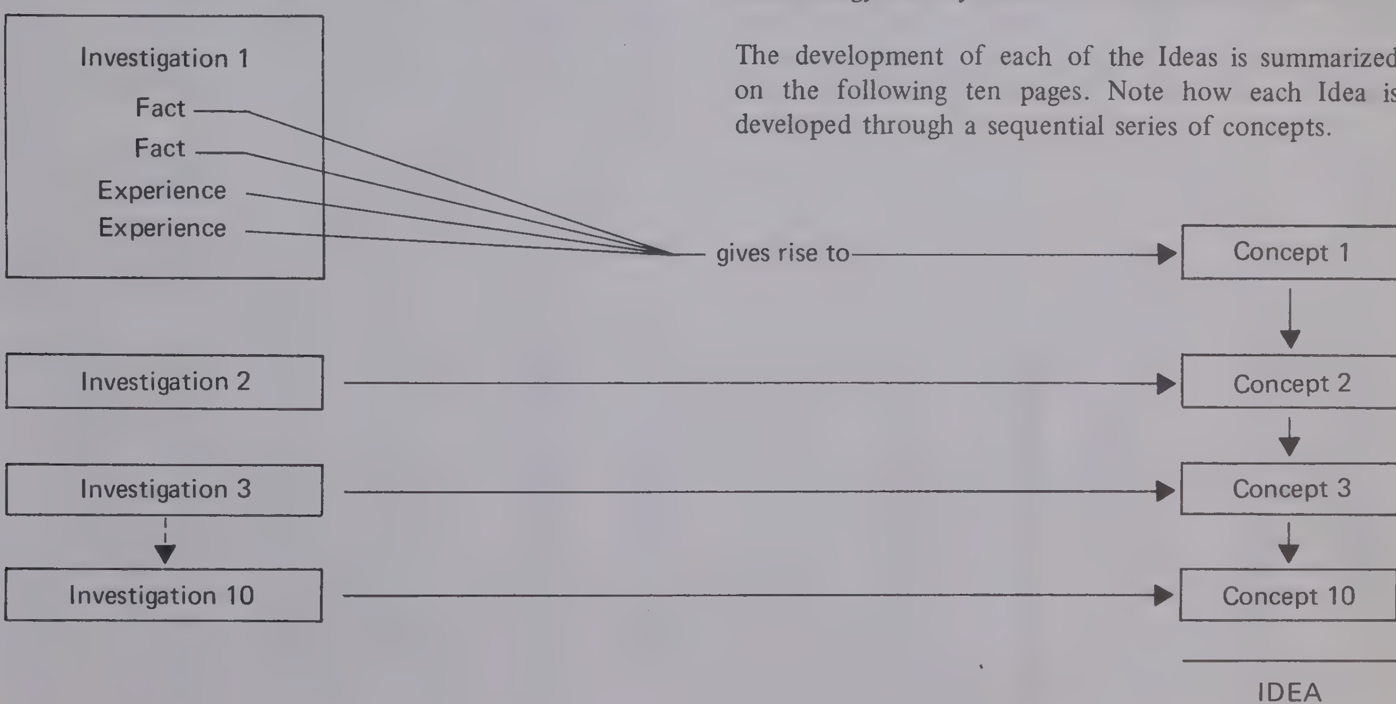
Biology Idea 2, *Evolution:* The great diversity of life has come about because living things have been changing through time.

Biology Idea 3, *Genetics:* All living things have passed on traits from generation to generation with a continuity of pattern.

Biology Idea 4, *Homeostasis:* Life is a continuous struggle to keep various processes at a suitable balance.

Biology Idea 5, *Ecology:* All living things constantly need energy as they interact with their environment.

The development of each of the Ideas is summarized on the following ten pages. Note how each Idea is developed through a sequential series of concepts.



## PHYSICAL SCIENCE: IDEA ONE (PREDICTING)

### Science Is an Attitude, a Method, an Activity of Man Interested in Finding Out More About His Natural Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. DO YOU SEE WHAT I SEE? | The recognition of problems depends on accurate observations. | Describing hidden objects; interpreting photographs |
| 2. IT'S A REGULAR HAPPENING | Natural events tend to repeat themselves. | Swing pendulums; Cartesian divers; shake bottles |
| 3. WHAT DO YOU PREDICT? | A prediction (hypothesis) is made to direct the possible solution of a problem. | Different kinds of balls dropped |
| 4. PUT UP OR SHUT UP | The purpose of an experiment is to supply evidence to support or reject the prediction. | Weights bounced on hanging springs |
| 5. BIGGER THAN WHAT? | Experiments must have controls. | Pendulums with different weights |
| 6. STANDARD SIZE | There must be standards of measurement. | Making toy fences with nonuniform bolts and nuts |
| 7. OH, IT'S DOWN YONDER | Accuracy is improved when measurements are recorded as numbers. | Filling 1 cc and 1000 cc plastic cubes with water |
| 8. WILL YOU BE A DROPOUT? | Tables simplify the recording of data. | Measuring heights of balls' bounces; pendulums of different lengths; making data tables |
| 9. 40,000 JOBS LOST PER WEEK | Graphs simplify the interpreting of data. | Making and interpreting graphs |
| 10. DON'T STOP ME, MAN—I'M REALLY MOVING | Conclusions must be based on the evidence (data) collected. | Timing the roll of balls |
| 11. SCIENCE IS WHERE THE ACTION IS! | Summary of concepts from first 10 investigations. | Using scientific method to solve a game-type problem; 2 persons joined at wrists by string |

## PHYSICAL SCIENCE: IDEA TWO (MATTER)

### The Universe Is Composed of Matter and All Matter Is Made of Tiny Particles

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. THAT'S ABOUT THE SIZE OF IT | All matter has the properties of weight and volume. | Weighing and measuring various objects |
| 2. JUST HOW MUCH IS IN THAT BAG? | Density is the ratio of weight and volume. | Computing density from weight and volume |
| 3. TIME FOR A THAW | The total amount of matter present remains the same whether it takes the form of a solid, liquid, or gas. | Weighing ice and water |
| 4. A ROSE BY ANY OTHER NAME | The amount of matter remains constant during a change of state. | Weighing and melting sulfur |
| 5. SOMEHOW IT'S NOT THE SAME | The total amount of matter present remains the same during a chemical change. | Weighing substances before and after a chemical change |
| 6. ONE AND ONE DON'T MAKE TWO? | Matter acts as though it is made of particles. | Measuring volume of solutions and mixtures |
| 7. IT'S A GAS | Matter reacts in constant proportions. | Measuring products of reaction of magnesium and hydrochloric acid |
| 8. LET'S BREAK SOMETHING | Matter breaks up in constant proportions. | Electrolysis of water |
| 9. DON'T GO TO PIECES | Matter is composed of different elements, each consisting of atoms. | Heating mercuric oxide; decomposing sodium peroxide in sulfuric acid |
| 10. WHAT GOES ON IN THERE? | Atoms contain smaller particles. | Static electricity; electroscope; Geiger counter; graphing radioactive decay |
| 11. MAKE YOUR OWN PIECES | Atoms are made up of protons, neutrons, and electrons. | Knocking marbles out of a circle |

## PHYSICAL SCIENCE: IDEA THREE (ENERGY)

### When Particles of Matter Interact, Energy May Be Either Released or Absorbed

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. I COULD WATCH IT BY THE HOUR | Work is force acting over a distance. | Rolling a spool with a rubber band; getting heat from bending a paper clip |
| 2. IT'S ALWAYS WORK | Work takes many forms, such as light, heat, and electricity. | Radiometer; electromagnet |
| 3. THERE MUST BE AN EASIER WAY | Work is made easier with simple machines. | Measurements based on pulley; lever |
| 4. IS THIS ON THE LEVEL? | Simple machines make work easier by using less force over a longer distance. | Measurements on an inclined plane |
| 5. HEAT MAKES WORK AND WORK MAKES HEAT AND– | Burning fuel does work through the expansion of heated gases. | Motion of test tubes and pin wheels produced by expanding gases |
| 6. STOP FUELIN' AROUND | Fuels release energy by reacting with other matter. | Paper burned in closed container; temperature changes from dissolving chemicals |
| 7. GO MAD WITH POWER | Energy comes from reacting nuclei of atoms. | Exposure of film by radiation and heat; solar cell; a simulated chain reaction with wooden blocks |
| 8. DON'T LET IT RUB OFF ON YOU | Radiation safety depends on shielding, space, and money. | Geiger counter readings with changes in distance and in shielding |
| 9. BUT YOU CAN'T GET SOMETHING FOR NOTHING! | Energy may be either released or absorbed when particles of matter interact. | The conversion of matter to energy demonstrated through use of simple arithmetic |

## PHYSICAL SCIENCE: IDEA FOUR (INTERACTION)

### Matter and Energy Are Constantly Interacting, Producing Our Changing Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. NOTHING IS FOREVER | Our surroundings are constantly changing. | Inspecting weather maps, sunspot photos, and moon photos |
| 2. IT'S A BREEZE | Interacting heat energy and air cause wind. | Heating sand and water by radiation; blowing up a balloon with hot air; the Coriolis effect |
| 3. IT'S NOT THE HEAT; IT'S THE HUMIDITY | Moisture in the air is controlled by interacting water, air, and energy. | Evaporating and condensing water; forming fog in a jar |
| 4. WE WALK ON IT DAILY | Interacting matter and energy wear away the surface of the earth. | Cracking a jar by freezing water; fracturing plaster by embedded beans; reacting lemon juice with calcite |
| 5. OUR GREAT BIG LAYER CAKE | Interacting matter and energy form new layers of the earth's surface. | Evaporating copper sulfate solution; examining fossils; forming sedimentary layers in a milk carton |
| 6. GROW SOME ROCKS | Interacting matter and energy form new materials in the earth. | Melting, dissolving, and recrystalizing crystals; forming an insoluble substance by combining a soluble crystal with sodium silicate |
| 7. WHAT GOES DOWN MUST COME UP | Interacting matter and energy raise and lower the surface of the earth. | Inspecting marine fossils from mountains; melting ice allowing floating board to rise; demonstrating isostasy in silly putty using metal cylinder |
| 8. WHAT'S GOING ON DOWN THERE? | Energy waves give information about the earth. | Sending waves through springs; interpreting seismograph records |
| 9. IT GETS LATE TOO EARLY | The amount of radiant energy reaching the earth changes regularly with time. | Analyzing fuel bills; measuring sun's angle; studying average temperatures |
| 10. SOMEWHERE IN SPACE | Energy from objects in space is used to locate them. | Measuring angles and distances with range finder; parallax |
| 11. THE STARS TELL ALL | Energy from objects in space is used to tell what they are made of. | Heating objects to incandescence; seeing through a prism the spectrum of ordinary light; observing through a grating solid and gaseous spectra |
| 12. TURN RIGHT FOR SUNSHINE | The moving earth causes the energy changes that produce the seasons. | Illustrating the seasons at different latitudes with a sphere |

## PHYSICAL SCIENCE: IDEA FIVE (TECHNOLOGY)

### Man's Understanding of the Interactions of Matter and Energy Allows Him to Control His Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. YOU TURN ME ON | Switches let us control energy. | Operating simple switches and thermostats |
| 2. BLOCK THAT BREEZE | We use matter to control the energy around us. | Insulating ice with paper; testing samples for thermal and electrical conduction |
| 3. I MADE IT MYSELF | We are surrounded by a man-made environment. | Mixing concrete; making a urea-formaldehyde synthetic which will glue wood |
| 4. THE FORCE TO MOVE MOUNTAINS | Useful work may be done when energy changes form. | Changing electrical energy to light, heat, and magnetism; making electricity with electrodes in salt solution and detecting it with an ammeter |
| 5. IT'S DONE WITH WIRES | Magnetic energy may be converted to electrical energy. | Producing electricity by poking magnet and electromagnet inside a coil; blowing a 0.2 amp fuse |
| 6. MOTORS TURN YOU ON | Interacting electricity and magnetism can do work. | Producing turning-forces by magnets and electromagnets; assembling and operating electric motor |
| 7. YOU GET IT HERE AND LEAVE IT THERE | Transportation depends upon interacting matter and energy. | Investigating aerodynamics with paper strips and Ping Pong ball; studying inertia |
| 8. MAKING THE BIG SOUND | Interacting electricity and magnetism can produce sound. | Assembling telegraph and speaker; investigating an earphone |
| 9. SORRY, WRONG NUMBER | Sound may be converted to patterns of electrical resistance, making speech over long distances possible with wires. | Vibrating rulers and rubber bands; changing the current by changing the resistance; assembling microphone and using it with earphone |
| 10. IT'S NOT FOR REAL | Understanding magnetic waves lets us send pictures through space. | Inspecting movie film; showing animation by flip-pictures; showing illusion of motion by string of lights; analyzing and reconstructing optical image |
| 11. YOU HAVE TO STAY SHARP | An understanding of technological uses of matter and energy is needed to be safe in our man-made world. | Producing chlorine from household chemicals; burning nail polish, remover, and absorbent cotton; comparing the slipping ease of rubber-backed and plain carpets |

## BIOLOGY: IDEA ONE (INQUIRY)

### Science Is an Activity, a Way in Which Man Discovers More About His Natural World

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. WHATEVER TURNS YOU ON | A problem is recognized when a person senses something that does not agree with his mental ideas. | Discrepant events: lemon and soda in tea; card blowing; chair lifting |
| 2. MAN, WE NEED CHANGES | The recognition of problems depends on accurate observations. | Chewing crackers; mealworm observations; 9 square game |
| 3. DON'T BE AFRAID TO GUESS | A scientist makes predictions to guide the solutions to a problem. | Germinating seeds wrapped in different plastics; guessing objects in sealed box |
| 4. PETALUMA IS A SWINGING TOWN | Controlled experiments are run to test the predictions. | Analyzing breath for carbon dioxide; constructing controlled experiment |
| 5. WEIRD HAROLD WEIGHS 45,500 | Accuracy is improved when common units and numbers are used. | Creating units and determining length, weight, and volume |
| 6. LET'S GET ORGANIZED | Results of experiments should be organized into data tables. | Measuring pupil size against light intensity |
| 7. CAN YOU SEE AS WELL AS JOSÉ? | Graphs should be used to aid in the organization and interpretation of data. | Designing histograms, bar graphs, and line graphs |
| 8. DO YOUR OWN THING | Conclusions must be based on the evidence collected. | Interpreting tables, graphs, and experimental data; observing weight changes in soaked seeds |
| 9. IF IT'S HAPPENING, BABY, IT'S HAPPENING TO YOU | Science is an activity, a thinking process, used by man to solve problems about his natural world. | Two inquiry problems |

## BIOLOGY: IDEA TWO (EVOLUTION)

### The Great Diversity of Life Has Come About Because Living Things Have Been Changing Through Time

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. YOU CAN'T HELP BUT BUMP INTO ONE | There are many different kinds of living things (diversity). | Photographs showing diversity |
| 2. DON'T CALL IT DIRT | There are many different kinds of life in soil. | Isolation of organisms from soil |
| 3. HUMAN SENSES ARE SO POOR | Microscopes extend the senses to help us see the great diversity of life. | Use of the microscope |
| 4. WHAT'S SO COMPLICATED ABOUT WATER? | There is a great diversity of life in a drop of water. | Observation of organisms in water |
| 5. ALL MEN ARE CREATED EQUAL | Despite the diversity of life, all living things are made of cells. | Observation of various cells |
| 6. IS THERE ORDER TO CHAOS? | Living things can be arranged into related groups (classification). | Grouping cards and cutouts |
| 7. PUNCH CARD A YELLOW-BELLIED SAP-SUCKER? | Order in classification is based on body structure. | Sorting data punch cards |
| 8. YOU CAN'T SEE THE FOREST FOR THE ROCKS | Fossils furnish evidence for living things in prehistoric days. | Making fossil replicas |
| 9. A HORSE, IS A HORSE, IS A HORSE? | Fossils furnish evidence that living things have changed through time. | Graphing growth of horse |
| 10. VARIETY IS THE SPICE OF LIFE | There is variation within each species. | Graphing pea size, leaf length, reaction distance |
| 11. SURVIVAL OF THE FATTEST | Nature selects the fittest to survive. | Selecting out colored cutouts |
| 12. PEOPLE ARE BEAUTIFUL | Skin coloration is the result of natural selection. | Reading on origin of skin coloration |

## BIOLOGY: IDEA THREE (GENETICS)

### All Living Things Have Passed on Traits from Generation to Generation with a Continuity of Pattern

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. AND THE BEAT GOES ON | Life comes from previous life. | Pasteur swan-neck experiment |
| 2. DON'T CROWD ME, BABY | A population can multiply very rapidly. | Bacterial growth; population control |
| 3. LOOK MA, NO PA | Some organisms reproduce by dividing, a method requiring only one parent (asexual). | Observation of ameba, paramecium, yeast, hydra, and onion root tip cells |
| 4. DON'T PEAS COME IN CANS? | In sexual reproduction, two cells are involved and the offspring do not look like the parents. | Flower dissection; pollen tube formation |
| 4A. THE EPIDEMIC NO ONE TALKS ABOUT | Venereal disease is a serious problem of epidemic proportions. | Reading about venereal diseases |
| 5. THAT'S USING THE OLD BEAN | A pattern of inheritance can be observed over a period of generations. | Analyzing a series of bean crops |
| 6. LET'S HAVE A PEA PICKIN' TIME | The pattern of inheritance can be predicted. | Analyzing a series of pea crops |
| 7. WILL YOUR PREDICTION GO UP IN SMOKE? | The environment can affect the appearance of an inherited feature. | Examining genetic tobacco seedlings |
| 8. WHAT'S A CLEAR CHIP WORTH? | Each offspring receives one "bit of information" for each feature from each parent. | Selecting plastic chips which represent features; model building |
| 9. IT'S A DOG'S LIFE | One "bit of information" can dominate and hide another "bit of information." | Review of Investigations 5 to 8; plastic chips |
| 10. IT TAKES BRAINS TO GAMBLE | You can determine the odds on the features an offspring will inherit. | Calculating odds |
| 11. WRINKLED PEAS FOR DINNER? | A "bit of information" can direct the activities of a cell. | Conversion of sugar to starch with pea seed enzyme |
| 12. I AM THE SECRET OF LIFE | The hereditary "bits of information" are carried on the chromosomes (as a chemical substance called DNA). | Observing chromosomes; karyotyping |

## BIOLOGY: IDEA FOUR (HOMEOSTASIS)

### Life Is a Continuous Struggle to Keep Various Processes at a Suitable Balance

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. ARE YOU GROOVY AND IN GEAR? | Living things must respond to a stimulus. | Response experiments with seeds, pulse rate, and snails |
| 2. LET'S COOL IT | Different stimuli can cause different responses. | Heartbeat rate of Daphnia; capillary flow in a goldfish |
| 3. NO SWEAT | Each response is made to keep the organism at a constant state. | Measuring sweat gland activity and body temperature |
| 4. WE MUST WORK TOGETHER | Different body functions must work together to keep the body at a constant state. | Measuring pulse, breathing, and gas production rate |
| 5. THE BIGGEST PUT-ON IN LIFE | Overstress can upset a constant state. | Smoking and breathing |
| 6. KEEP YOUR COOL AND KEEP IT STEADY | Each body function operates best at its particular constant state. | Digestion of starch with enzymes |
| 7. A REAL MOVING STORY | Membranes help the body to regulate its constant state. | Diffusion and osmosis |
| 8. HOW'S YOUR BLOOD SUGAR? | Hormones help the body regulate its constant state. | Effect of hormones on seeds and chicks |
| 9. WHAT'S THIS SCENE ALL ABOUT? | The nervous system coordinates the life functions necessary to maintain a constant state. | Drug abuse |
| 10. THE GAME OF HOMEOSTASIS | Life is a continuous struggle to keep various processes at a constant state. | Academic game with cards |

## BIOLOGY: IDEA FIVE (ECOLOGY)

### All Living Things Constantly Need Energy as They Interact with Their Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. YOU EAT NEARLY A TON OF FOOD | All living things constantly need energy. | Burning nuts; measuring calories |
| 2. A STORY THAT'S FULL OF HOLES | Plants need carbon dioxide and light to make starch. | Finding stomates; testing leaves for starch |
| 3. THE IMPORTANCE OF BEING GREEN | Plants need chlorophyll to maintain life. | Chromatography of chlorophyll |
| 4. YOUR LIFE DEPENDS ON PLANTS | Plants produce oxygen. | Measuring oxygen production |
| 5. BUBBLE, BUBBLE, TOIL—NO TROUBLE | Carbon dioxide is released when food is broken down for energy. | Respiration of yeast |
| 6. LOOK, THERE IN THE FOOD! | Living things need oxygen to release energy if life is to continue. | Respiration of pea seeds |
| 7. A CITY FULL OF NATURE | A community is an organized group of populations living in mutual dependence (and is dependent upon energy for survival). | Ecological survey |
| 8. A MOLD CAN SAVE YOUR LIFE | All living things compete with other living things for the available energy in a food web. | Bacterial competition |
| 9. IT'S A SMALL WORLD | A succession of organisms can be observed in a community until a climax is established. | Succession of microorganisms |
| 10. BEAUTIFUL DOWNTOWN BURBANK | Destructive influences can upset a climax community. | Measurement of oxygen; pollution |

## How Is Inquiry Used to Teach Content in IIS?

The style and strategy of teaching IIS are extremely simple. Each investigation is designed so that the student, with the teacher's guidance, discovers one concept at a time. Each series of investigations is a sequential development of concepts. The selection of concepts and processes has been made in terms of the students' intellectual, social, motivational, and educational maturity.

The IIS approach uses a series of concrete experiences as a foundation on which concepts are built: *The student forms the concept; he does not receive it.* The IIS materials are tailored to the unique characteristics of the uninvolved student:

1. He cherishes his experiences because they are tangible to him. Also, he often has more patience with the mechanical details of laboratory experiments than gifted students do.

2. He can draw conclusions and formulate concepts better when he discovers these from his own practical experiences.

3. He learns well from group verbal interactions and personal experiences, but does not learn well from books.

4. He can comprehend related facts leading to the understanding of a larger idea, but soon forgets unrelated facts.

5. He likes to be challenged, but without pressure and within his capabilities. He enjoys the physical challenge of manipulating laboratory equipment.

6. He thrives on success.

The IIS program provides opportunities for the students to practice some of the same kinds of inquiry processes that scientists use in their investigations. The ideas of science are taught from an inductive-discovery approach. This approach also best meets the characteristic behaviors of the educationally uninvolved student.

Each time a learning experience is provided, it is built upon what has come before it and creates a "readiness" for the next learning experience. This readiness assures maximum "success experience" from the very beginning.

Science concepts are man-made and tentative, subject to constant evaluation, modification, and clarification. Much of the IIS program directs the students toward the processes and methods of seeking answers in the laboratory, rather than toward exact answers.

Ten major processes have been identified for use in the IIS program. These processes are common to all science programs that use inquiry to develop conceptual understanding. The terms associated with these processes are:

Observing
Classifying
Inferring
Predicting
Measuring
Communicating
Interpreting Data
Formulating Questions
Experimenting
Formulating Models

The descriptions that follow will help to clarify the meaning of these terms. Each description is also keyed to one example of many from the IIS program.

| Process | IIS Example |
|---|---|
| *Observing:* Observations are made in a variety of ways using one, several, or all of the senses. | *Biology Idea 1, Investigation 2:* The students observe the behavior of a mealworm, sense the change of taste of a cracker, and try to figure out a puzzle. |
| *Classifying:* Classifying is the grouping or ordering of objects and events according to a scheme devised by the observer. | *Biology Idea 2, Investigation 7:* The student transfers morphological information about 15 animals to a set of data punch cards. The cards are coded, punched, and sorted to separate the animals into similar groups. |
| *Inferring:* An inference is a statement developed from a set of related observations. Inference requires evaluation and judgment. | *Biology Idea 3, Investigation 7:* After observing three generations of beans and peas, the student sees a second generation crop of tobacco seedlings and is asked to infer its parental background. |
| *Predicting:* Prediction is the formulation of an expected result based on past experience. The reliability of prediction depends upon the accuracy of past observations and the ability to make inferences from a set of observations. | *Physical Science Idea 2, Investigation 11:* Students repeatedly roll a marble down a ramp into a cluster of differently colored marbles. From the results of this experiment, they predict the nuclear structure of the atom. |
| *Measuring:* Measuring is the determination of the magnitude of selected properties. The units of measure can be arbitrary or standardized. | *Physical Science Idea 2, Investigation 3:* The student weighs $H_2O$ first as ice, and then as water, to determine if there is any difference after a physical change. |
| *Communicating:* Communication is the process of describing, recording, and reporting experimental procedures and results to others. For clarity, tables and graphs may be used. | *Physical Science Idea 1, Investigation 10:* The student writes a paper describing what kind of ball rolls downhill the fastest. |
| *Interpreting Data:* The interpretation of data requires that a student assess the validity, precision, and usefulness of the data. | *Physical Science Idea 3, Investigation 3:* The student must interpret data generated by making measurements on the motion of pulleys and levers. |
| *Formulating Questions:* Questions are based on previous observations and usually precede attempts to evaluate a situation or event. They usually arise from inferences and give rise to predictions which must be tested. | *Biology Idea 3, Investigation 12:* After observing various patterns of inheritance, the student is guided to ask the question, "What and where are the 'bits of information' that influence the features received by an offspring?" |
| *Experimenting:* Experimenting involves designing data-gathering procedures and then gathering the data needed to test a prediction. Variables must be identified and controlled as much as possible. | *Biology Idea 5, Investigation 6:* The student tests germinating and nongerminating seeds to determine their relative rates of gas production. |
| *Formulating Models:* A model is a physical or mental representation of what the observer infers is the real object or event. Models are used to describe the interrelationships of concepts and ideas. | *Physical Science Idea 2, Investigation 6:* The students use popcorn and puffed rice to formulate a model of the particulate nature of matter. |

## How Is IIS Socially Relevant?

The IIS program is socially relevant in three important ways. First, Biology Idea 1 and Physical Science Idea 1 both develop the idea that science is man-made and is but one of the many activities of man. Second, scientific problems with social implications are considered. Third, the student becomes personally involved because he must make a value judgment on social problems.

To be relevant, a science course must be concerned with the relationships between science, technology, society, and the individual. IIS considers the following cultural implications of science:

1. *Aesthetic* beauty can come from the excitement of discovery and the simplicity of conceptual explanations.

2. Scientific endeavors are universal, without cultural or ethnic boundaries. They have a potential for developing bonds of common *philosophical* ideas between peoples of the world.

3. Science can thrive best under a government that is basically democratic. Many *political* decisions require scientific judgment.

4. Scientific and technological advances have a strong influence on *economic* development. In turn, a society's economic needs influence the rate of scientific and technological advance.

5. The rapid accumulation of scientific and technological knowledge has created a need for deeper insights into scientific-*sociological* problems.

IIS involves the student in an analysis of current scientific problems having social implications. Among the socially relevant topics the students discuss, analyze, and make judgments about are:

| Socially Relevant Topic | Investigation |
|---|---|
| Automation | Physical Science Idea 3, Investigation 4 |
| Drug Abuse | Biology Idea 4, Investigation 9 |
| Education | Physical Science Idea 1, Investigation 8 |
| Education | Biology Idea 1, Investigations 7 and 8 |
| Employment | Physical Science Idea 1, Investigation 9 |
| Home Safety | Physical Science Idea 5, Investigation 11 |
| Information Explosion | Physical Science Idea 1, Investigation 10 |
| Information Explosion | Biology Idea 1, Investigation 9 |
| Natural Resources | Physical Science Idea 4, Investigation 7 |
| Nuclear Testing | Physical Science Idea 2, Investigation 10 |
| Nuclear Testing | Physical Science Idea 3, Investigation 8 |
| Pollution (Noise) | Physical Science Idea 1, Investigation 11 |
| Pollution | Physical Science Idea 3, Investigation 5 |
| Pollution | Biology Idea 5, Investigation 10 |
| Population Explosion | Biology Idea 2, Investigation 2 |
| Racial Prejudice | Biology Idea 2, Investigation 12 |
| Smoking | Biology Idea 4, Investigation 5 |
| Space Race | Physical Science Idea 4, Investigation 10 |
| Urbanization | Biology Idea 5, Investigation 9 |

Through these topics, the IIS program hopefully will provide the individual student with a deeper insight into his attitudes and values toward society.

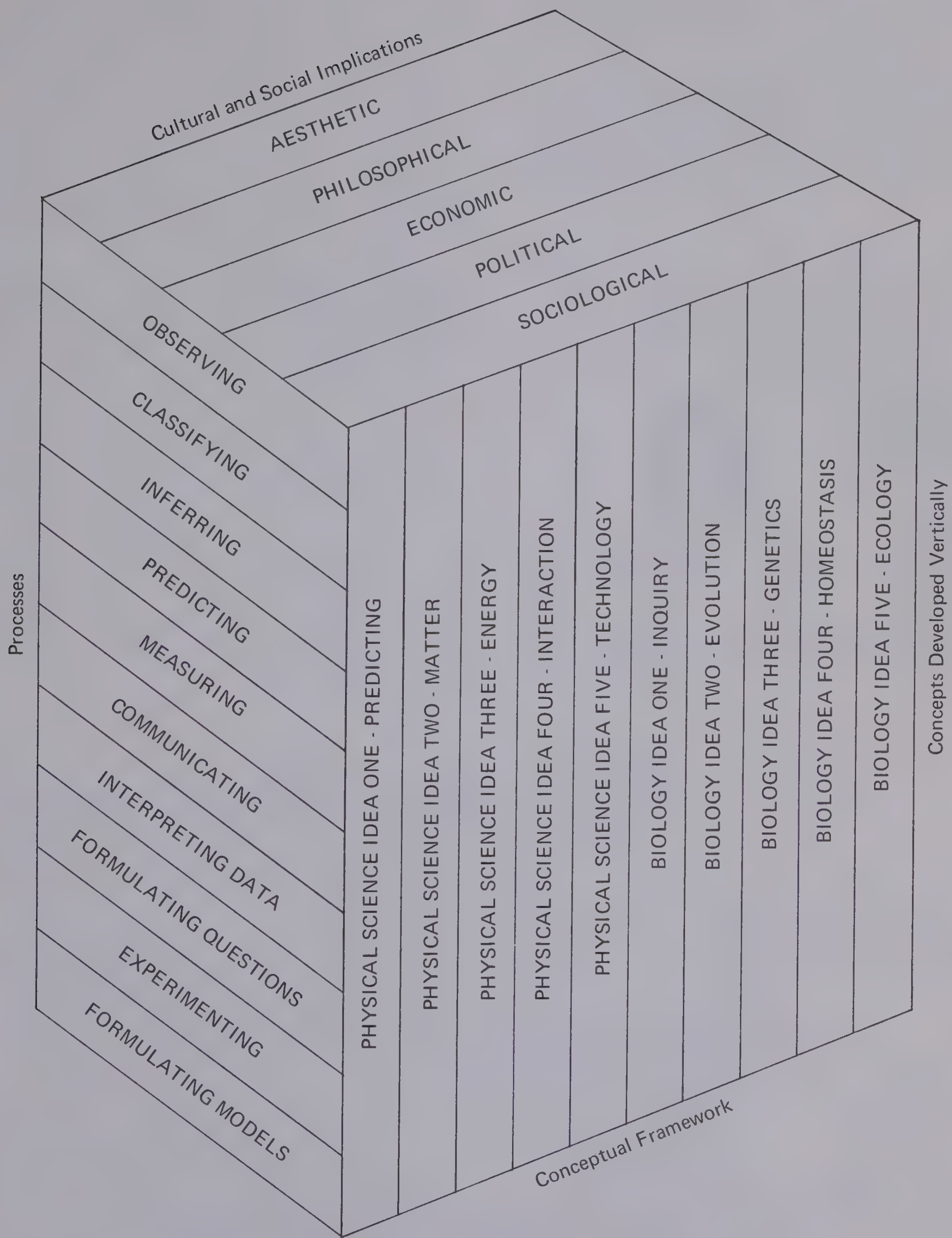
## What Is the IIS Matrix?

There are three levels of learning in the IIS program—concepts, processes, and values. The three levels of learning do not take place in isolation. Attitudes, cognitive processes, and concepts must be learned as a totality of human experience.

The IIS program forms a three-dimensional matrix which encompasses

a. the conceptual framework of science
b. the processes of science
c. the cultural and social implications of science

THE IIS MATRIX



## How to Teach the Program

No extensive orientation is needed to teach IIS, but you must keep in mind that the student is the focal point of the IIS program.

Your introductory remarks to the class should make science sound interesting and easy. Keep all your remarks positive. The one most important thing you should say is that the students will succeed and have fun learning IIS.


It is one thing to tell students they will succeed; it is another to prove it. The following characteristics of the program and suggestions of procedure will help do so.

1. In each Idea, all of the investigations for one student are bound together in consecutive order. The student data sheets follow each investigation. (The data sheets are bound separately in the hardbound version.)

2. When the students arrive for the first investigation, distribute a Data File to each student. Explain that all work will be done in class and that the folder will be a convenient place to store lessons from day to day.

3. Point out to the students the inside back cover of the Idea titled, "IDEA SUMMARY." On this page the student is to maintain a running summary of the concepts discovered in each investigation. (For the clothbound edition, the IDEA Summary sheets are found in the Data Book.)

4. The first investigation in the Idea should be separated from the book before class. Distribute one to each student and indicate that the rest of the course will be similar. It may take a week before the students believe you, but tell them that they will be working on laboratory investigations one after another.

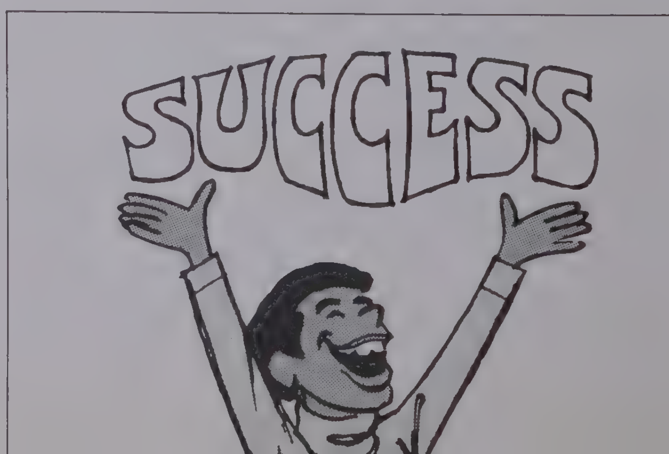
5. The IIS program is designed so that all of the work can be done in class. There is no need to give any exams, term papers, or homework, unless the teacher or student so desires. Impress upon the students that they have the ability to do all the investigations. They will be working in groups of two to four, but the results will be dependent on individual effort. You will be there to help them, but they will do most of the work themselves. With this combination, they are bound to succeed.

6. At the end of each class period, collect all the folders and keep them in a cabinet, on shelves in the classroom, or even in a cardboard box. It will not be necessary for the students to take their folders home. The rationale behind this is:

a. By doing the work in class, a 95% work turn-in can be realized. If the work has been done properly, a good grade should be given. Such performance and reward breeds confidence and success in a student.

b. The homework pattern of the uninvolved student is poor. If homework is taken home, the result is frequently a lost assignment or failure to do it. Homework is a phenomenon of the college-prep student and his future professional world. In the future world of most IIS students, there will be no homework. They will be judged by their performance on the job.

7. If you find it necessary to make rules at the beginning of the course, assure the students that the rules are simply to provide smooth operation of the course: If they are to succeed, they will want to have everything running smoothly *in their favor.*



The motivation you provide is of great importance in securing success for your students. The following techniques are useful:

1. The students should be praised every time an investigation is returned. Never take a negative attitude!

2. Never compare one student's paper to another. Instead, make suggestions as to how *all* the investigations can be improved. Remind students about the format for data tables, graphs, accuracy of measurement, correct English, and just plain neatness.

3. When you return an investigation, quickly summarize the activities performed, and then ask the students what concept they learned. When the class agrees on the concept, have the students enter this in the Idea Summary on the inside of the back cover.

4. Use visual aids to help the students see how the concepts are being developed sequentially. Each concept, as it is discovered, can be printed on cardboard strips and tacked to a bulletin board. Each new concept, as it is discovered, can also be unveiled with the use of an overhead projector. The students can then see daily where they have been, what they are pondering now, and where they may be going. Finally when the Idea is completed, they can see its overall development.

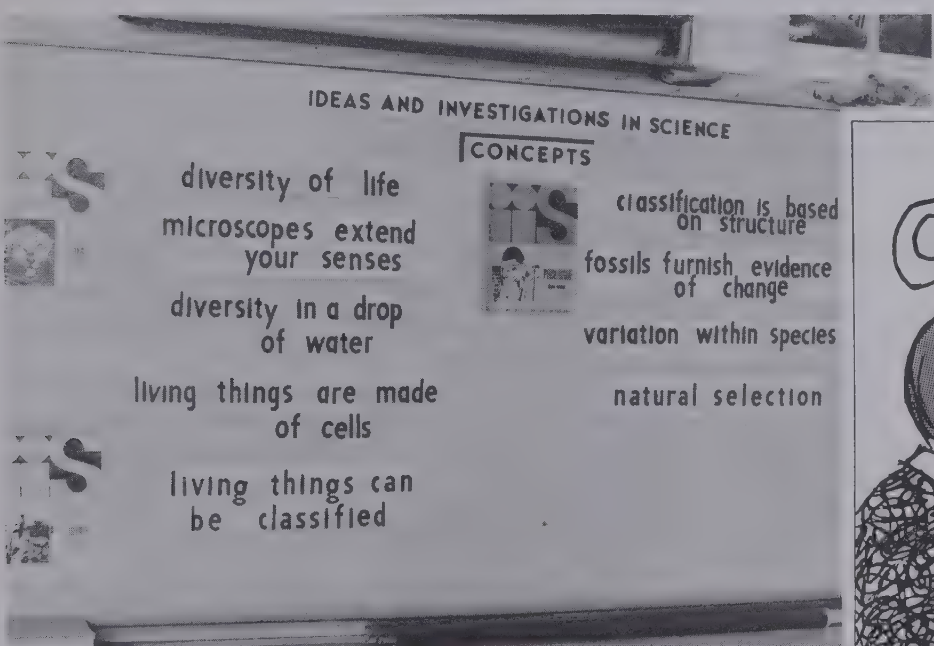
5. Before you start a new investigation, you should review all of the concepts studied previously. *Do not read the concepts.* Rather, summarize the data from each investigation and ask the students to draw the appropriate concept.

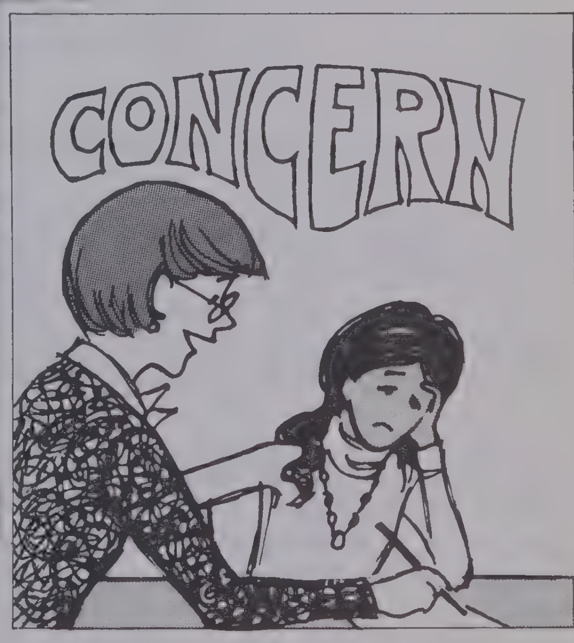
6. When you distribute an investigation, it may be necessary to read parts of the text and instructions to the students. You may need to demonstrate what has to be done, especially the set-up of equipment. You should even show and name the equipment because scientific and household equipment may be foreign to these students.

7. Many of the investigations are designed for groups of two students; in others, groups of four students are appropriate. You can keep these groups together as you circulate to assist, counsel, and "patrol." Become involved with the students in the laboratory and remove yourself from the front of the room.

8. Try not to answer questions. Instead, counter with other questions to assist the student in making his own discoveries.

The success of IIS does depend to a great extent on the attitude of the teacher. The role of the teacher in the IIS program is that of a helper and motivator. You must convey to the students your trust and faith in them. It will take a while for the students to realize that you believe in them. In the meantime, keep smiling!



## How to Prepare Each Laboratory Investigation

IIS is designed with the average high school laboratory situation in mind. The laboratory used for the IIS program must have tables for the students to work on and the usual assortment of equipment and supplies; e.g., microscopes, balances, and glassware.

IIS is not an expensive laboratory program, since most of the items should already be available in any average-stocked science department. Items which are unique to the IIS program or are difficult to obtain are available through Prentice-Hall, Inc. Other items of a household nature can be obtained at the least expense locally.

A comprehensive list of materials needed for each level of IIS (Biology or Physical Science) is provided at the back of the Teachers Manual for that level. Use it as a guide to determine the materials you need.

Since almost every day in IIS is spent in the laboratory, the materials for each investigation should be organized in advance. The materials for each investigation are listed in the guide to that particular investigation. Materials are listed for each team of two (or four) students, so that if aides or assistants are available, they can be enlisted to prepare the materials needed for each team.

An easy way of organizing materials for each team of students is to place them in individual tote-trays. These can vary from fiberglass trays to dishpans, plastic trays, shoeboxes, cardboard box bottoms, and coffee cans. Laboratory preparation and dismantling can take place in a separate room and the trays be moved from class to class if necessary.

## How to Use the Manual to Plan Each Day

The IIS program is structured in a step-by-step procedure which allows the student to experience a continued series of accomplishments. Each investigation is organized in a sequence of learning steps that help each student discover the concept of the investigation.

The organization of IIS provides students with the routine they need for a secure learning environment, but there is no monotony to this routine because there is variety in the activities from one investigation to the next.

Each investigation has its own unique characteristics, and you should read the portion of the Teachers Manual for each investigation. The following pattern is used in the Manual.

TITLE AND NUMBER: This identifies the investigation. The guide for each investigation can be easily removed from the Manual and put in a 3-ring binder with the investigation itself.

TIME: The times noted are for class periods of approximately 45-50 minutes and represent an average to above-average length of time. The times are given as an aid in planning, and you may not want to adhere to them.


REMINDER: These occasional reminders, indicated by the accompanying cartoon, refer to important details in the investigation or its preparation.

PURPOSE: This gives the concept to be developed in the investigation.

DEVELOPMENT: The development of each concept is stated in a few brief sentences. First, the laboratory activities are mentioned, and second, the discussion and questions that accompany the activities.

HIGHLIGHT: Each investigation has its own unique feature of special interest to the student. It may be a simple cartoon, game, laboratory experience, or a series of questions.

LOOK AHEAD: If an advance preparation is particularly necessary, it is noted here. The teacher should always be preparing an investigation or two ahead.

MATERIALS: The materials are listed for each team of two or four students or for the class as a whole. Materials needed by the teacher are also listed.

*Preparation of Materials:* The directions for the preparation of any special materials are given here.

TEACHING TIPS: This section comprises the main body of the guide for each investigation. It is divided into three subheadings.

*Responses to Expect:* Expected student responses and how to cope with them.

*Practical Hints:* An assortment of helpful hints.

*Discussion and Review:* Suggestions on how to handle the data and the questions that accompany each experiment.

ENRICHMENT: For those who find it necessary to assign extra work, a list of suggestions is given. However, you are cautioned to give extra assignments sparingly. If you have any students who finish early, give them the responsibility of helping to maintain the materials or of helping other students. The latter is especially valuable for them.

REFERENCES: This section is divided into two parts.

*Books and Articles:* Most of these references are for teacher background reading. You are, however, encouraged to keep reading material available for the students, too. Although uninvolved students are usually not interested in reading, you should encourage those of them who are.

*Multi-Media Aids:* These range from films to film loops, slides, filmstrips, overlays, special lab kits, records, and tapes. The sources are indicated. A list of distributors of these aids, with addresses, is provided at the back of the Teachers Manual for each level.

POSSIBLE ANSWERS: In many cases, no precise answer can be given; therefore only possible answers are listed. For convenience, these answers can be transferred to your copy of the student data sheet, or next to the question in the student text.

CONCEPT SUMMARY: Allow for considerable latitude in the way students express the concept.

### What to Read for Background


Fantini, Mario D., and Gerald Weinstein, *The Disadvantaged: Challenge to Education.* New York: Harper & Row, 1968.

Frost, Joe L., and Glenn R. Hawkes, *The Disadvantaged Child: Issues and Innovations.* Boston: Houghton Mifflin, 1966.

Johnson, G. Orville, *Education for the Slow Learners.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1963.

Passow, A.H., *Education in Depressed Areas.* New York: Teachers College Press, 1963.

Riessman, Frank, *Helping the Disadvantaged Pupil to Learn More Easily.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1966.

Strom, Robert D., *Teaching in the Slum School.* Columbus, Ohio: Charles E. Merrill, 1965.

Witty, Paul A., ed., *The Educationally Retarded and Disadvantaged.* Chicago: University of Chicago Press, 1967.

# Idea 1
## Predicting

IIS PHYSICAL SCIENCE has been divided into five major Ideas. A series of investigations, each presenting a concept, provides the logical sequence of steps that enables the students to discover a major Idea.

In this first Idea, 11 investigations are used to present the opening Idea that:

SCIENCE IS AN ACTIVITY OF MAN, A METHOD OF UNDERSTANDING HIS ENVIRONMENT.

The investigations may be lumped into three areas. The first five investigations develop the techniques for solving problems. The next four study the problem-solving tools used in science, measurement and the need for standards in measurement, and how best to organize data so that interpretation is easier. Finally in the last two investigations, students apply to practical situations what they learned in the previous investigations, and from the concepts the investigations furnished, they formulate the major Idea.

Be familiar with the entire Idea before you start. Have all of the materials available to prevent last minute crises. Not less than two to three days' time should be allowed for preparation of equipment for each investigation, so that the frequent interruptions of school routine that plague us all won't leave you unprepared.

It is often to your advantage to keep one or two investigations ahead so that you may take full advantage of an unexpected block of time due to a cancelled activity or a nonappearing film.

# PHYSICAL SCIENCE: IDEA ONE (PREDICTING)

## Science Is an Attitude, a Method, an Activity of Man Interested in Finding Out More About His Natural Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. DO YOU SEE WHAT I SEE? | The recognition of problems depends on accurate observations. | Describing hidden objects; interpreting photographs |
| 2. IT'S A REGULAR HAPPENING | Natural events tend to repeat themselves. | Swing pendulums; Cartesian divers; shake bottles |
| 3. WHAT DO YOU PREDICT? | A prediction (hypothesis) is made to direct the possible solution of a problem. | Different kinds of balls dropped |
| 4. PUT UP OR SHUT UP | The purpose of an experiment is to supply evidence to support or reject the prediction. | Weights bounced on hanging springs |
| 5. BIGGER THAN WHAT? | Experiments must have controls. | Pendulums with different weights |
| 6. STANDARD SIZE | There must be standards of measurement. | Making toy fences with nonuniform bolts and nuts |
| 7. OH, IT'S DOWN YONDER | Accuracy is improved when measurements are recorded as numbers. | Filling 1 cc and 1000 cc plastic cubes with water |
| 8. WILL YOU BE A DROPOUT? | Tables simplify the recording of data. | Measuring heights of balls' bounces; pendulums of different lengths; making data tables |
| 9. 40,000 JOBS LOST PER WEEK | Graphs simplify the interpreting of data. | Making and interpreting graphs |
| 10. DON'T STOP ME, MAN—I'M REALLY MOVING | Conclusions must be based on the evidence (data) collected. | Timing the roll of balls |
| 11. SCIENCE IS WHERE THE ACTION IS! | Summary of concepts from first 10 investigations. | Using scientific method to solve a game-type problem; 2 persons joined at wrists by string |

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 1 (2-3 periods)

**PURPOSE**: Show the need for accurate observation in understanding common events.

**DEVELOPMENT**: (A) and (B) Students, searching among a collection of objects in a paper bag, will try to pick out objects from classmates' descriptions.

They will observe for significant details (C) a news photograph in the text and (D) the behavior of a pendulum in the laboratory.

Students will discuss the difference between observations and interpretations.

**HIGHLIGHTS**: Objects in the paper bags are well enough described so that all students come up with the same object (No. 4, page 3).

**MATERIALS** (for each team of two)

*Part A–Describing miscellaneous objects*
Bag, paper, heavy duty lunch size to contain assortment below
Miscellaneous assortment of objects, such as:

- balloon
- gum eraser
- hairpin
- ice cream stick
- marble
- paper clip
- pencil
- pencil eraser
- piece of brick
- rock
- safety pin
- short dowel
- spring
- typewriter eraser
- wire

*Part B–Describing various balls*
Ball set:

- Ping-Pong, white
- rubber, 1" diameter, white
- rubber, 2" diameter, white
- rubber, 3" diameter, white
- styrofoam, 3" diameter, white
- plastic, 2" diameter, white
- tennis

Bag, paper, heavy duty lunch size to contain the balls above

*Part D–Pendulum*
String, cotton, 18" long
Tape, masking, ½" width, a few inches long (Keep a roll in a central location and let students tear off what they need.)
Paper clip, standard size
Washer, metal, ¾" outside diameter

**Preparation of Materials**

Fill the bags with the assortments in advance. Once made up, they may be stored from year to year with only minor replacements.

## TEACHING TIPS

**Responses to Expect:** Some students will probably complain that the wounded officer's shield is not visible, or that a shield doesn't make a policeman. For the record: the officer is Ernest Rowell of the Cleveland police force. He was wounded during a disturbance. The photograph appeared July 23, 1968. There may be debate on whether a policeman is one of the good guys or bad guys.

**Practical Hints:** To start the idea of description, hold up an object not in the bag, such as a football, and have the class describe it. Write the description on the board as it comes in. Some dictionaries describe a football as ellipsoidal, but don't expect that term to be volunteered.

Let the class work on part C (observing the police photo) by themselves before discussing it. The need to be observant will be brought home more dramatically.

Let the students improvise their own method of timing the pendulum. Timing will be provided in the next investigation. This will stimulate them to thinking about measurement.

**Discussion and Review:** Let the students do the answering. You can hint and use leading questions, but the actual words about accuracy of observation must come from them. Don't ask for a stiffly formal statement. Let students answer in their own words. If they may only answer in the teacher's language, they will soon be reluctant to answer at all.

When grading these first papers, remember success is important, as is time. It is more important that the papers come back promptly with good grades than that they be painstakingly evaluated.

## ENRICHMENT

This is really too early for too much additional load. If time and circumstances permit, the tried and true psychology class stunt of having someone burst into the room and shout, or do something innocuous, can be used. For example, a student could run in, go to the back of the room, and shout, "Be careful" while he bends over and looks under a lab table. Statements about what happened can be compared and the differences discussed. In answering, some students will describe their observations (the boy ran in . . .) while others will give their interpretations (he was chasing a rat that was loose in the hall; or, the gas connection at the lab table was leaking). Point out the difference between observations and interpretations.

## REFERENCES


### Books

Atkins, K. R., *Physics.* New York: John Wiley & Sons, 1965. Pp. 1-2.

Thurston, J., and R. G. Carraher, *Optical Illusions.* New York: Reinhold Publishing Corp., 1966.

Tolansky, S., *Optical Illusions.* New York: Pergamon Press, 1964.

### Multi-Media Aids

*Science Study Skills:* 16 mm, color or black and white, 11 min., Coronet Films Cat. No. 1594.

*Shapes:* Film loop, Encyclopaedia Britannica Cat. No. 80780.


## POSSIBLE ANSWERS

1. No. (Or at least not the first time.) They were not sure which object was being described.
2. The description must be close enough for everyone to get it.
3. As an example, a description of a ball bearing might be: ball-shaped; ½ inch in diameter; about the weight of a half-dollar; shiny appearance similar to that of a nickel or dime; very hard.
4. Hopefully, everyone did, but some may not because descriptions were not clear and accurate.
5. The description must be accurate and clear.
6. Some students will say that he's being arrested, but the badge on his shirt and the insignia (barely visible on his right sleeve) suggest that he's a police officer being helped in an emergency by the other two men.
7. He is wearing a badge and is probably a policeman.
8. The washer takes the same time for each swing no matter how far you pull it back.
9. It takes the same time for each swing.
10. No.
11. No.
12. The rhythm remains the same regardless of whether the arc of the swing is small or large.
13. Observe carefully. (Really see what he's looking at.)
14. To avoid mistakes, to have accurate information, to avoid jumping to conclusions.

**CONCEPT SUMMARY**: One thing scientists do is observe events carefully.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 2 (2 periods)

**PURPOSE**: Introduce the concept of the consistency of nature.

**DEVELOPMENT**: When (A) swinging a pendulum, (B) shaking a jar of materials in water, or (C) squeezing a Cartesian diver, the students will learn that the same initial set of conditions produces the same results.

(D) Expanding the idea from the data, the student will see that causes produce their effects in an orderly manner.

**HIGHLIGHTS**: The pendulum has the same period when the distance it is pulled aside changes (No. 5, page 6).

The diver always sinks under pressure and rises when released (No. 20, page 8).

**MATERIALS** (for each team of two)

*Part A–Pendulum*
Tape, masking, 2" length
Paper clip, standard size
String, cotton, 18" length
Washer, metal, ¾" outside diameter

*Part B–Objects in water-filled jar*
Ping-Pong ball
Gravel, fine, about 10 ml
Thread, 2 to 4 inches long
Jar, 1 qt., widemouthed, watertight lid

*Part C–Cartesian diver*
Jar, 1 pt., clear plastic, watertight lid
Eyedropper, 1½" glass section

**MATERIALS** (for the class)

Clock with second hand, or metronome

**Preparation of Materials**

Place a handful of fine gravel, a foot of thread, and a Ping-Pong ball in each jar. Fill them all about three-fourths full of water and cap them securely.

Cartesian divers may be prepared by using soft, clear plastic squeeze bottles. Use an eyedropper for the float. If the dropper is partly filled with water so that it barely floats, a moderate amount of pressure on the tightly capped bottle will make the dropper sink. It will bob back up as soon as the pressure is released.

**TEACHING TIPS**

**Responses to Expect**: Students will ask how the diver works? Don't tell them. Instead ask them to find out how well they observe what is happening. Eventually, someone will notice (or *know*) that the water level in the eyedropper rises when the bottle is squeezed.

What does shaking a jar have to do with science? Answer by asking students what they can learn from it.

**Practical Hints**: By this time you should have established when the concept of each investigation is to be transcribed to the sheet or folder used to summarize the whole Idea. Some teachers prefer to do this before the investigations are turned in for grading, others would rather wait until they have returned the graded sheets and there is more agreement. Do whichever you feel is better for your own style of teaching.

If the students hold the pendulum almost horizontal, there will be a change in the number of swings. Try to limit them to moderate displacements.

**Discussion and Review**: Build up from the fact that the pendulums kept giving the same number of swings. Then ask how much change there was between shakings of the jar of water. Finally, ask if the float ever rose when the bottle was squeezed.

The idea that events repeat themselves will then come from the class: they will discover that nature is consistent, that the same circumstances produce the same results (or whatever original way the students choose to phrase it).

## ENRICHMENT

Have a student make a double or triple diver, in which each diver sinks one after the other as the pressure is increased.

## REFERENCES

### Books

Shortley, G., and D. Williams, *Principles of College Physics.* Englewood Cliffs, N. J.: Prentice-Hall, Inc., 1967. Page 234.

Taffel, Alexander, *Physics: Its Methods and Meanings.* Rockleigh, N. J.: Allyn & Bacon, Inc., 1969. Page 97.

Williams, John E., H. Clark Metcalfe, Frederick E. Trinklein, and Ralph W. Lefler, *Modern Physics.* New York: Holt, Rinehart, & Winston, 1968. Pp. 121-122.

### Multi-Media Aids

*Introduction to Physics:* 16 mm, color or black and white, 11 min., Coronet Films Cat. No. 365.

## POSSIBLE ANSWERS

The swings for the first three trials will run about 40 per minute.

1. They are all (almost) the same.
2. The same number. (The second set of three trials will be the same as the first.)
3. They are the same as the first three trials.
4. The same number.
5. They are the same.
6. They get the same number of swings both times.
7. The same as us.
8. The same results.
9. The ball floats, the thread hangs in the middle, and the gravel sinks to the bottom.
10. The same places.
11. The same places.
12. The same places.
13. The same places.
14. The same places.
15. You get the same results.
16. Yes; you expect the ball to float on a lake because it repeatedly floated in the jar. (This answer assumes that students consider lake water to be essentially similar to the water in the jar, and that other essential conditions are similar in the two sets of circumstances.)
17. The diver sinks.
18. The diver rises to the surface.
19. The same thing happens.
20. The same.
21. The same results.
22. The same results. Location on the Earth has no effect on results.
23. The same procedure gives the same results.
24. . . . give the same results.

**CONCEPT SUMMARY**: The same set of conditions give the same results.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 3 (1-1½ periods)

**PURPOSE**: Propose the prediction, hypothesis, or educated guess as a means of directing the solution of problems.

**DEVELOPMENT**: (A) and (B) Students will drop balls singly and in pairs and will compare their rates of descent.

The falling balls are an opening gambit to arouse students' curiosities in a manner that will encourage them to make predictions.

**HIGHLIGHT**: The two balls hit at the same time (No. 11, page 10).

**MATERIALS** (for each team of two)

Ball set used in Investigation 1

**TEACHING TIPS**

**Responses to Expect**: Outside of "Why do we have to do this?" the class may still be apathetic. Slower students have had their normal curiosities blunted; it takes time to overcome this. They are accustomed to failing, and apathy is their defense against this. Without being patronizing, encourage and reassure them whenever you can.

**Practical Hints**: You will be working to stimulate curiosity. Hold the different balls up. Ask questions such as, "Will a green ball fall faster than a red one?" "Will a rough ball bounce higher than a smooth one?" Use this to lead into formulating questions for number 15, "List problems you could investigate with the balls."

In number 16, you will have to help some students verbalize what they think will happen. This is done by circulating among them, getting to as many students as possible.

Collect the balls during this period in order to deny students the opportunity of expressing their frustrations graphically on the softer, more vulnerable balls. A certain amount of this is probably inevitable; note that you can remove a great deal of the *ball point* scribbling by rubbing it with an alcohol dampened rag.

**Discussion and Review**: The opening section reviews the idea of consistency. The activity then leads into the ways balls behave. Students at first have trouble making predictions about things they have little experience observing. But preliminary experimenting will start them wondering and once they have questions to work from, the predicting comes more easily.

**ENRICHMENT**

Have students try predicting the weather, the outcome of athletic events, etc. Have them keep a record of the success and failure of their predictions.

Have a student who feels he has a special gift for it make predictions using cards, a crystal ball, or some other such method. Have him keep a record of the accuracy of his predictions.

**REFERENCES**

**Books**

Stollberg, R., and Faith Fitch Hill, *Physics Fundamentals and Frontiers.* Boston: Houghton Mifflin, 1965. Pp. 1-9.

**Multi-Media Aids**

*The Scientific Method:* 16 mm, color, 12 min., Encyclopaedia Britannica Films Cat. No. 703.

**POSSIBLE ANSWERS**

1. It fell and bounced.
2. It will fall and bounce.
3. That's what happened last time. (The same conditions give the same results. Consistency, etc.)
4. It fell and bounced.
5. The same thing.
6. It would fall and bounce.
7. The same thing.
8. It will fall and bounce. (The same thing.)
9. Yes. The same conditions give the same results.
10. The balls will hit the floor at the same time. (Probably.)
11. The balls hit the floor at the same time.
12. Yes. The same conditions give the same results. (Consistency, etc.)
13. The same thing. The same conditions are used.
14. Nature is consistent. (The same conditions give the same results.)
15. Students' answers. (They could compare falling times of balls of different weights, sizes, colors, smoothness, etc., or they could compare their bouncing ability.)
16. Students' answers. (The predictions follow the questions. Heavier balls fall faster, slower, or the same, etc.)
17. He makes a prediction (guess).

**CONCEPT SUMMARY**: Scientists make predictions to help find answers to their problems.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 4 (1½ periods)

**PURPOSE**: Show that experimenting is a logical step in testing predictions.

**DEVELOPMENT**: (A) The students will observe the up and down bobbing of weights suspended from springs, and (B) from these observations they will make and test predictions about their motions.

The fact that not all predictions are verified by the data drives home the need for testing. Logic is not enough.

**HIGHLIGHT**: No matter how far down a student stretches the spring, the weight bounces the same number of times per minute (No. 13 and No. 15, page 14).

**MATERIALS** (for each team of two)

*Parts A & B—Weights bobbing on a spring*
Spring, steel spiral, 1.5 cm diameter, 4 cm long, Welch 0569C or equivalent
Weight, 3 oz. lead fishing sinker
Weight, 8 oz. lead fishing sinker
Ruler, 12" metric
String, cotton, 4" length
Support for spring: ring stand and burette clamp, or let it swing from the side of the table

**MATERIALS** (for the class)

Clock with second hand, or metronome

**TEACHING TIPS**

**Responses to Expect**: Students may ask, "What's this good for?" Answer: What must engineers know when they design springs for cars, diving boards, or watch springs.

**Practical Hints**: There will have to be a division of labor. One student counts bounces while the other marks time.

Choose your spring and weight combinations so they don't oscillate too fast to count. The reason why the time of oscillation remains constant for varying distances of stretch is too mathematical for the class to go into. They can be told individually, if they ask after finishing, that the extra pull of the spring makes the weight move faster and thereby makes up for the longer distance it travels.

**Discussion and Review**: The theme is simple: *you don't know until you try it.* Many students intuitively feel the heavier weight will move more slowly, but they may be caught off base because their intuition was wrong in predicting that a change in amplitude of swing would cause a change in the swing's period.

The discussion should have the class in agreement that you don't know something is so until you test it.

**ENRICHMENT**

Let some student discover Hook's Law: *the distance a spring stretches is proportional to the force producing the stretch.* The relationship between time and weight involves a square root which is usually beyond the class's mathematical competence.

**REFERENCES**

**Books**

Shortley, G. H., and D. E. Williams, *Principles of College Physics,* 2nd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1967. Page 232.

Taffel, Alexander, *Physics: Its Methods and Meanings.* Rockleigh, N.J.: Allyn & Bacon, 1969. Page 96.

Williams, J. E., H. C. Metcalfe, F. E. Trinklein, and R. W. Lefler, *Modern Physics.* New York: Holt, Rinehart, & Winston, 1968. Pp. 119-120.

**POSSIBLE ANSWERS**

1. Test it.
2. Students' data.
3. Students' predictions.
4. Students' data. (The heavier weight was slower, made fewer bounces per minute, etc.)
5. There might be a goof (error). More confidence can be placed in the accuracy of a result if it can be gotten consistently.
6. The same results. (The heavier weight is slower).
7. The same result.
8. (It depends upon the prediction.)
9. I found out what really happens. *Or* that the prediction was wrong. *Or* how springs work, etc.
10. No.
11. Students' predictions. (They may guess more bounces, the same number or less.)
12. Try it.
13. It was the same. The same number of bounces both times. The distance didn't matter.
14. To make sure it's consistent, to eliminate error, etc.
15. The same thing. The distance didn't matter.
16. An experiment. To see if it is right, to see if it comes true, etc.

**CONCEPT SUMMARY**: Predictions must be tested to see if they are true.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 5 (1-2 periods)


Make the pendulum strings different lengths for different teams. They should range from 12 to 24 inches.

**PURPOSE**: Develop the concept of the control.

**DEVELOPMENT**: In their further study of the pendulum, different groups of students will get different frequencies (due to varying string lengths). This will bring out the need for controlling variables in order to make meaningful comparisons.

**HIGHLIGHT**: Students learn that different pendulum lengths give different results (No. 11, page 16).

**MATERIALS** (for each team of two)

*Part A–Pendulum*
String, cotton, length: from 12 to 24" long, *but do not inform students that the lengths are different for different teams*
Paper clip, standard size
Washer, metal, about ¾" outside diameter–3 are needed
Tape, masking, 3" length

**MATERIALS** (for the class)

Clock with second hand, or metronome

**TEACHING TIPS**

**Responses to Expect**: Some students will probably ask why adding more washers doesn't make the pendulum change speed? Perhaps it is because in a sense the washers are falling, and they found elsewhere that all weights fall at the same speed. Don't go into it any more deeply since the physics and math involved are too much at this point.

**Practical Hints**: Don't permit intergroup visiting until the time to check results. The fact that the pendulums have different lengths is to be held back until students cross-check data.

You may have to help with question 11 if no one sees the difference in pendulums.

**Discussion and Review**: The whole theme here is that a result is significant only when it can be compared to something else. Every homerun hitter is compared to Babe Ruth.

Try some comparisons in class just for fun. Whom do the kids use as a standard for wealth, beauty, sex, brawn, etc.?

## ENRICHMENT

Let some students try a number of different pendulum lengths: see if they can discover that a pendulum four times the length of another takes twice as long to complete a swing.

Let some students try bobbing different weights on springs. Hopefully, they may find that a weight four times as great as another takes twice as long to bob up and down.

To qualify for a speed record a vehicle must travel the course first in one direction, and then in the opposite direction a short time later. The times for each direction are then averaged to give the official time. Students interested in racing may know why this averaging procedure is used, and they may want to explain it to the rest of the class.

## REFERENCES

### Books

Blanc, S. S., A. S. Fischler, and O. Gardner, *Modern Science: Man, Matter, and Energy*. New York: Holt, Rinehart, & Winston, 1967. Page xxvi.

### Multi-Media Aids

*What Is Science* (2nd ed.): 16 mm, color or black and white, Coronet Films Cat. No. 1627.

*Scientific Method in Action:* 16 mm, 19 min., International Film Distributors, Inc.

## POSSIBLE ANSWERS

1. They are the same.
2. Distance pulled back has no effect on number of swings per minute.
3. The same results.
4. No difference.
5. The same as before.
6. It has no effect.
7. There is no effect.
8. He would get the same results.
9. About the same. (Hopefully, if no one has caught on to the different string lengths.)
10. No.
11. It may be either to different pendulum lengths or to some factor we don't know about yet.
12. No. The pendulums were all different lengths. Two sets of conditions were allowed to change instead of only one.
13. It doesn't say longer than what.
14. It doesn't say what the balls are bigger than or what they bounce higher than.
15. It is an experiment in which only one thing is changed at a time.

**CONCEPT SUMMARY**: Experiments must have controls.


The screws and nuts furnished each group should not mate.

**PURPOSE**: To establish the need for standard units.

**DEVELOPMENT**: Students will learn the need for standards (A) by trying to compare desk widths measured in different arbitrary units and (B) by attempting to join chicken coop screening with mismated nuts and bolts.

Students will understand the benefits of standardization as applied to their everyday lives.

**HIGHLIGHT**: Students find that their mismatched nuts and bolts cannot be used to fasten together the pieces of wire screen (No. 7, page 18).

**MATERIALS** (for each team of two)

*Part A–Homemade ruler*
Wood, 1/8" x 12"
Tape, masking, about 13" long

*Part B–Matching nuts to bolts*
Screens, wire, ¼ inch mesh, 3" x 3"–3 are needed
Bolts, 10-24, 3/8" long or 10-32, 1/2" long, alternate teams getting the same size–6 are needed
Nuts, hexagonal, 10-24 or 10-32, teams with 10-24 bolts get 10-32 nuts and vice versa–6 are needed
Ruler, 12" metric

**Preparation of Materials**

In part A, if the masking tape is run the length of the wood stick, the graduations may be placed on the tape, and the tape removed after each group does the experiment.

In part B, the 10-32 bolts are deliberately a little longer than the 10-24's in order to make sorting easier. Have the screens, nuts, and bolts in a tray, shoe box, or other convenient container beforehand. Make sure that a container with 10-24 bolts has 10-32 nuts, and vice versa. Distribute these containers so that adjacent groups have dissimilar bolts: This will facilitate the exchange of bolts between groups part way through the experiment.

## TEACHING TIPS

**Responses to Expect**: Some students won't read ahead far enough to expect trouble with the bolts. When they complain, tell them to borrow other bolts.

The idea of making their own ruler is new. Some students will ask for advice on how to use it when there is a fraction of a unit at one end. Tell them to estimate the distance, using simple fractions like ¼, ½, and ¾.

**Practical Hints**: Do not issue the materials for part B until A is completed. The ruler used in B would destroy the whole impact of part A.

As soon as the students have caught on to the difference in bolts and nuts, have them start counting threads. When this data has been collected, gather up the equipment before further discussion. Small articles are a distraction when they are easily handled, misplaced, or thrown.

Have the students sort out the two different sizes of bolts and nuts as much as possible to cut down the time to prepare the materials for the next class. If you use aluminum nuts for one size thread and steel for the other, they can be sorted easily by a magnet.

Students who have traveled between the U.S. and Canada may know that U.S. quarts and gallons are different from Canadian quarts and gallons. Save any allusions to Mexico or other metric countries for the next investigation, but don't squelch an eager student in the process.

**Discussion and Review**: This is a two-pronged attack on the need for standards: one, the need for standard units of measure and two, the need for standard designs. Generally boys are in a better position to see these points because of their problems with mismated car parts; the prepackaged kitchen does not give the girls much measuring to do.

If the girls have done some sewing, they may be able to realize some of the problems involved in trying to fit a sleeve into a garment when the parts were cut to different scales.

You may want to discuss unwritten standards, like always arriving a half hour after the party was supposed to start.

## ENRICHMENT

Readers may be enticed into reading about ancient or biblical measure: cubit, donum, actus, or barleycorn are a few.

Some boys may be interested in the problems of the medieval armorers who mated each bolt and nut as a unit: as a result there was only one nut that would fit a given bolt.

Boys may demonstrate micrometers and other measuring instruments they are familiar with; girls might be interested in colonial forms of measuring cups, spoons, etc.

## REFERENCES

### Books

Adler, Irving, *The Tools of Science.* New York: John Day Co., 1958. Pp. 7-24.

Asimov, Isaac, *Realm of Measure.* Boston: Houghton Mifflin, 1960.

Blanc, S. S., A. S. Fischler, and O. Gardner, *Modern Science: Man, Matter, and Energy.* New York: Holt, Rinehart, & Winston, 1967, pp. xxx-xxxi.

Carona, Philip B., *Things that Measure.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1962.

General Electric, *Precision: A Measure of Progress.* Pamphlet.

Irwin, Keith G., *Romance of Weights and Measures.* New York: Viking Press, 1960.

Perry, John, *Story of Standards.* New York: Funk & Wagnalls Co., 1955.

Woolf, Harry, ed., *Quantification: a History of the Meaning of Measurement in the Natural and Social Sciences.* Indianapolis, Ind.: Bobbs-Merrill Co., Inc., 1961.

**Multi-Media Aids**

*Using the Scientific Method:* 16 mm, color or black and white, 11 min., Coronet Films Cat. No. 618.

*Measurements Are for a Purpose:* Filmstrips and record

Part 1: *Standards and Measurements:* color, 54 frames, 14 min., SVE Cat. No. 562-1.
Part 2: *Measurement Systems and Theory:* color, 52 frames, 14 min., SVE Cat. No. 562.
Record for both Parts 1 and 2: SVE Cat. No. 562-IRR.

**POSSIBLE ANSWERS**

1. (Answers will vary.)
2. (Answers will vary.)
3. (Answers will vary.)
4. They are all the same.
5. No.
6. Have a common system of measurement.
7. (Answers will vary.)
8. Either 16 or 20 threads. (Students may be off one thread.)
9. So people will know whether the screws will fit what they want them for.
10. So that people can buy the correct size film for their camera.
11. So people can agree on what they mean (how much they pay for things, how much they are buying, etc.).
12. Yes. There are standard speeds, standard hole sizes, and standard size grooves in the record.
13. Standards are units everyone agrees to use. We need them to make things fit each other, agree on sizes, etc. Some standards are agreed upon by custom, others were worked out to fill a need.

**CONCEPT SUMMARY**: Standards of measurement make many of our activities possible.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 7 (1-1½ periods)

**PURPOSE**: Reinforce the idea of standards by introducing the metric system.

**DEVELOPMENT**: (A) The decimal nature of the metric system will be apparent when students examine a meter stick.

The advantages of a measuring system based on our decimal number system will be explored by making metric measurements (B) of length, (C) of volume, and (D & E) of mass. (F) Students will recognize that it is a standard accepted throughout the world.

**HIGHLIGHT**: Students see that the divisions on a meter stick are all tens and hundreds (No. 4 and No. 9, page 20).

**MATERIALS** (for each team of two)

*Part A–Metric volume*
Meter stick

*Part E–Mass*
Cylinder, graduated, 100 ml
Balance, platform
Cube, plastic, 1 ml
Eyedropper

*Part F–Universal*
(Meter stick from part A above)

**MATERIALS** (for the class)

*Part C–Volume (Teacher Demonstration)*
Cube, plastic, liter
Meter stick
Cylinder, graduated, 100 ml

*Part D–Mass*
Scale, bathroom, weighing in kilograms

*All Parts*
Wall chart of metric system
Several sets of weights, balances, and graduated cylinders

**Preparation of Materials**

Many bathroom scales may be taken apart by pulling up the thin pad on top and releasing the springs underneath. Paste a new set of numbers over the dial and reassemble. If IIS *Biology* is taught in your school, the teacher may have a scale you can use.

**TEACHING TIPS**

**Responses to Expect**: Mostly: Why do we need to know this stuff? You can point out that the U.S. probably is going over to it; students will need it for a job in a few more years. In some industries, such as pharmaceuticals, it is used now. Potential draftees need it: the military is mostly metric. It's useful for foreign travel.

When using metric rulers, you will avoid a lot of confusion if you refer to *spaces* rather than to lines: there are ten *spaces* between numbers, etc. Also expect confusion over centimeters and millimeters: most metric rulers have "mm" written on them, leading students to believe that the spaces between lines marked by numbers are millimeters (though actually centimeters).

**Practical Hints**: Don't set out to teach metric-English conversion. Answer, if asked how the units compare but, as the arithmetic is a drag, don't bring it up or push it.

Set out a few graduated cylinders and weights. Let the kids handle them. If you have some rugged balances, let students fool around with them. People always want to put the weights on the balances and see if the numbers come out.

Pushing through all the details of the metric system in one gulp is not practical. Keep the metric measuring instruments handy but only require the investigation.

Have the chart of the system on the wall for students to see. Use it to answer questions but not as a lecture prop.

**Discussion and Review**: Remember there are *two* things involved: the introduction to a system of measurement and the reinforcement of the concept of a standard.

The debate in the U.S. over the metric system will go on for some time. There will be current reports on the troubles of the British as they go through their estimated 10-year conversion period. When you start this section, see what is current in the press. Let the debate in class be lively but don't let the metric system obscure the other point: no matter what the standard is, a standard is needed.

## ENRICHMENT

Keep all of the measuring instruments available: balances, graduated cylinders of different sizes, sets of weights, etc. Students will usually want to weigh the various items in their purses and pockets: dark glasses, combs, wallets, and change.

Give some elementary instruction on how to use the balances and then allow free time to practice. When the novelty wears off, get down to work before any other activity takes its place.

## REFERENCES

### Books and Articles

Pella, Milton O., *Physical Science for Progress.* Englewood Cliffs, N.J.: Prentice-Hall, Inc. 1970. Pp. 10-11.

*The Physics Teacher.* 7:2, Feb. 1969. Pp. 72-73.

### Multi-Media Aids

*Comparison of English and Metric Systems:* Overhead transparency, School Products Co., Inc. Cat. No. Ch-6603.

*Experiments with Length:* Filmstrip, color, 41 frames, SVE Cat. No. 449-1.

*Measurement in Physical Science:* 16 mm, color or black and white, 13½ min. Coronet Films Cat. No. 1516.

*Metric System:* 16 mm, color or black and white, 11 min., Coronet Films Cat. No. 1090.

*The Metric System:* Filmstrip, black and white, 40 frames, McGraw-Hill Cat. No. 643010.

*Metric Units:* Transparency, School Products Co., Inc. Cat. No. 8300.

*The Metric Weights and Measures:* Filmstrip and record, Library Filmstrip Center.

Sanborn's P.O. Drawer 1210, McAllen, Texas 78502. A travel and insurance company has a sticker that converts miles to kilometers and gallons to liters. It is shaped like a speedometer.

## POSSIBLE ANSWERS

1. A standard.
2. 100.
3. The number in question 2.
4. 10.
5. The answer to question 4.
6. A cent.
7. A centimeter.

8. Millimeters.
9. 1,000.
10. (Answers will vary.)
11. (100 times the answer given in question 10.)
12. (1,000 times the answer given in question 10.)
13. (Answers will vary.)
14. (Answers will vary.)
15. Metric.
16. Kilometers.
17. 1,000.
18. 1,000.
19. Move the decimal two places to the right. (Add two zeros, etc.)
20. Move the decimal three places to the left. (Take off three zeros, etc.)
21. Multiply by a hundred. (Add two zeros, move the decimal point, etc.)
22. Divide by a thousand. (Take off three zeros, move the decimal point, etc.)
23. Millimeter, centimeter, meter, kilometer.
24. Milliliter.
25. They are the same.
26. 1,000 cc.
27. 1,000 ml.
28. They are the same.
29. (Answers will vary.) (Note: 1720 millimeters is about 5' 7¾")
30. Kilogram.
31. (Answers will vary.) (Note: 61 kilograms is 134 pounds.)
32. (Answers will vary.)
33. About right.
34. (Answers will vary.)
35. (Answers will vary, but the weight should increase by 100 g.)
36. 100 grams.
37. 100 cubic centimeters.
38. 1 gram.
39. (Answers will vary.)
40. (Answers will vary, but the weight should increase by one g.)
41. 1 gram.
42. 1 milliliter.
43. 1,000 times.
44. (Answer will depend on the width of the tables in your classroom.)
45. (Answer should be 1/10 the answer of question 44.)
46. (Answer should be 1/1,000 of the answer of question 44.)
47. It leaves us behind, out of it, etc. We lose out.
48. Because the parts are standardized.
49. So his results can be checked later by himself and by others.

**CONCEPT SUMMARY**: The metric system (1) is a standard widely used throughout the world, and (2) is based on units of ten like our number system.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 8 (2-3 periods)

**PURPOSE**: Show how tables organize data.

**DEVELOPMENT**: Students will see the value of a table for presenting data in an easily understood manner by tabulating data for (A) a bouncing ball experiment and (B) a pendulum experiment. (C) They will draw up a table correlating amount of education with earning power.

**HIGHLIGHTS**: The table gives a quick answer to student questions (No. 5, page 28).

The table shows who makes the best living (No. 12, page 30).

**MATERIALS** (for each team of two)

*Part A–Bouncing balls*
Ball set used in Investigation 1
Meter stick

*Part B–Pendulum*
String, cotton, 2 to 3 foot length
Paper clip, standard size
Washer, metal, ¾" outside diameter
Tape, masking, 3" length
(Meter stick from part A above)

**TEACHING TIPS**

**Responses to Expect**: Have the sports section of your local newspaper ready. When the why-do-we-learn-this starts, pull out the statistics' résumés that are run for baseball, basketball, or football leagues. Then counterattack with, "How long would it take you to find the leading hitter (or passer, or rebounder, or rushing-ground-gainer) if the data was scattered all over the page?"

When asked for help with a title, have the student start by trying to verbalize what he is trying to show. Then he can pare down the words and make it more elegant. You may want to do this with individuals, or with the whole class, or both, depending on the situation.

**Practical Hints**: Handle the balls when it's time for the prediction in part A. Squeeze them, heft them, and bounce them to help suggest predictions to the students.

Students will be measuring the bounding-heights in centimeters. Help with reading the meter sticks. The fact that tiny divisions are written as tenths in decimal form takes a while to become a part of the students' normal operations. They tend to make fractions out of everything at first.

The averaging process will also require aid. Work out one or two long divisions on the board, then check over students who are floundering with the math as you wander through the class. Have them round off to a tenth of a centimeter. If asked, say that answers are carried out as far as the data were taken: students only measured to a tenth of a cm.

In the pendulum table, they can round off to the nearest whole swing if that's how they took data.

In part C (earning power versus amount of education) let the students do the interpreting. Don't give a hard sell for education; they have heard it before. If pinned down, explain that these are the midpoints where people tend to cluster. Lots of people have beaten the odds, but it's always nice to have the odds on your side. Several hundred people have jumped off the Golden Gate Bridge, but the number of survivors can be counted on the fingers of one hand. In a diplomatic way, of course, ask students if they would buck those odds.

**Discussion and Review**: The use of tables will continue throughout the course. Students have considerable difficulty thinking of titles for tables. Make them realize that if they know what the table is for, they can come up with an appropriate title.

There may be time to discuss organization as a life style. Among slower students the present is all that matters; the idea that life can be organized is foreign to them, if not downright unacceptable. Don't push this; if you throw it out and it just lies there, forget it for the time being.

## ENRICHMENT

This is a limited area. Have some of the books listed as references around for inspection to show that tables are used and used and used.

## REFERENCES

### Books

Lang, Luman H., *The World Almanac.* Newspaper Enterprise Association, Inc., (Annual).

Lehrman, R. L., and C. Swartz, *Foundations of Physics.* New York: Holt, Rinehart, & Winston, 1965. Page 10.

U.S. Bureau of the Census. *Statistical Abstract of the United States.* 1968 (Annual).

Wattenberg, Ben J., and Richard M. Scammon, *This U.S.A.* Garden City, N.Y.: Doubleday & Company, Inc., 1965.

Zeisel, Hans, *Say It with Figures,* 5th ed. New York: Harper and Row, 1968.

## POSSIBLE ANSWERS

1. In a table or chart.
2. Students' predictions (hard, soft, heavy, light, large, small).
3. The same height.
4. Several times. To eliminate error; to see if the result is consistent, etc.
5. Students' observations (hard, soft, heavy, light, large, small).
6. It depends upon the original prediction. (See if the answers are "honest," but don't make a big fuss.)
7. Students' predictions. (Most will probably go for the short pendulum being fastest.)
8. (It depends upon the original prediction. The shortest pendulum was fastest, or a numerical answer.)
9. 1962.
10. Pabst.
11. 1946 (Note from Table 7 for the years 1964 and 1963 we have: 3,781,000 less 2,750,000 = 1,031,000 more persons reached 18. The difference in births 18 years earlier–from 1945 to 1946–would be greater, but would still be *about* a million.)
12. The longer you stay in school, the greater your earning chances.
13. They organize data to make it easier to understand.

TABLE NO. 8

THE RELATIONSHIP OF INCOME TO AMOUNT OF EDUCATION

| Years of Education | | Weekly Salary | Percent Higher than earliest dropout |
|---|---|---|---|
| 1. | Less than 8 | $ 86 | -- |
| 2. | 8 | 117 | 36 |
| 3. | Some H.S. | 138 | 60 |
| 4. | Finish H.S. | 158 | 84 |
| 5. | Some college | 178 | 107 |
| 6. | Finish college | 229 | 166 |

**CONCEPT SUMMARY**: Tables organize data to make it easier to understand.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 9 (2-3 periods)

**PURPOSE**: Show how graphs are used to present data quickly and clearly.

**DEVELOPMENT**: Students will learn how to interpret and draw (A) bar graphs, (B) line graphs, and (C) double bar graphs.

They will see that graphs display conveniently a great deal of common but important information.

**HIGHLIGHT**: The students see where the jobs are increasing and decreasing (No. 19, page 34).

**MATERIALS** (for each student)

*Parts A, B, C–Graphs*
Ruler, 12" metric

**TEACHING TIPS**

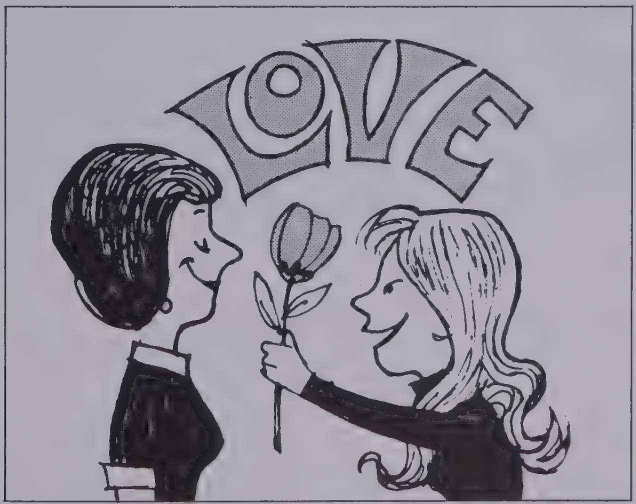
**Responses to Expect**: Students will ask, referring to Graph 2 (Children Born Per 1000 Women), why there was a minimum in births around 1940. Your explanation may be drawn from these facts: All during the period from the 19th Century onward people were moving to cities and didn't need large families to work the farm. During the depression of the thirties the birth rate dropped because people just couldn't support their children. The big upswing after 1940 was the result of improved economic conditions and the return of World War II veterans.

Students can understand much of this information. The growing dissemination of family planning information, started about the twenties is relevant but may be a topic better avoided. Judge for yourself. Don't give this information as a lecture. When someone asks, ask what was going on in the U.S. in the thirties, what happened in 1941, etc. The students will put the picture together.

**Practical Hints**: The biggest problem students have with graphing is using equal spaces to indicate equal magnitudes. In your wandering through the class, give aid with this problem without berating students; anything with numbers is discouraging enough. Patience!

Use a city map with a grid drawn on it to get over the idea of locating the points on a graph. Have students find the particular street in H8 or G11. Either get several maps from a gas station or use a copy machine to make a transparency.

Bring in graphs from the daily paper or news magazines. The stock market reports usually furnish something pertinent.



Let the students formulate their own opinions on the employment data, part C. Approach this from the "What can you learn from the graph?" angle. They can take it from there.

**Discussion and Review**: Remember, the point is graphing itself. The fact that other ideas about population or job potentials come up is an indication of the power of graphs.

In reviewing the graph, stress the main points: how to make and label axes properly and how to locate points. The simple idea of locating a point by two coordinates is a foreign notion to many students.

## ENRICHMENT

Have nautically or aeronautically minded students check how latitude and longitude are used to locate points.

## REFERENCES

### Books


Blanc, S. S., A. S. Fischler, and O. Gardner, *Modern Science: Forces, Change, and the Universe.* New York: Holt, Rinehart, & Winston, 1967. Pp. 11-12.

Galbraith, D. I., and D. G. Wilson, *Biological Science: Principles and Patterns of Life.* Biological Sciences Curriculum Study. New York: Holt, Rinehart, & Winston, 1966. Pp. 29-40.

Lehrman, R. L., and C. Swartz, *Foundations of Physics.* New York: Holt, Rinehart, and Winston, 1965. Pp. 10-12.

Lowenstein, Dyno, *Graphs: a First Book.* New York: Franklin Watts, Inc., 1969.


### Multi-Media Aids

*Graphs and Analysis of Data:* Transparency, School Products Co., Inc. Cat. No. Ph-6.00.

*Graphs: Pictographs, Bar, Line, Number Pairs, Maps:* Filmstrip, color, 47 frames, SVE Cat. No. 532-11.

*Introducing Graphs:* 16 mm, 11 min. McGraw-Hill.

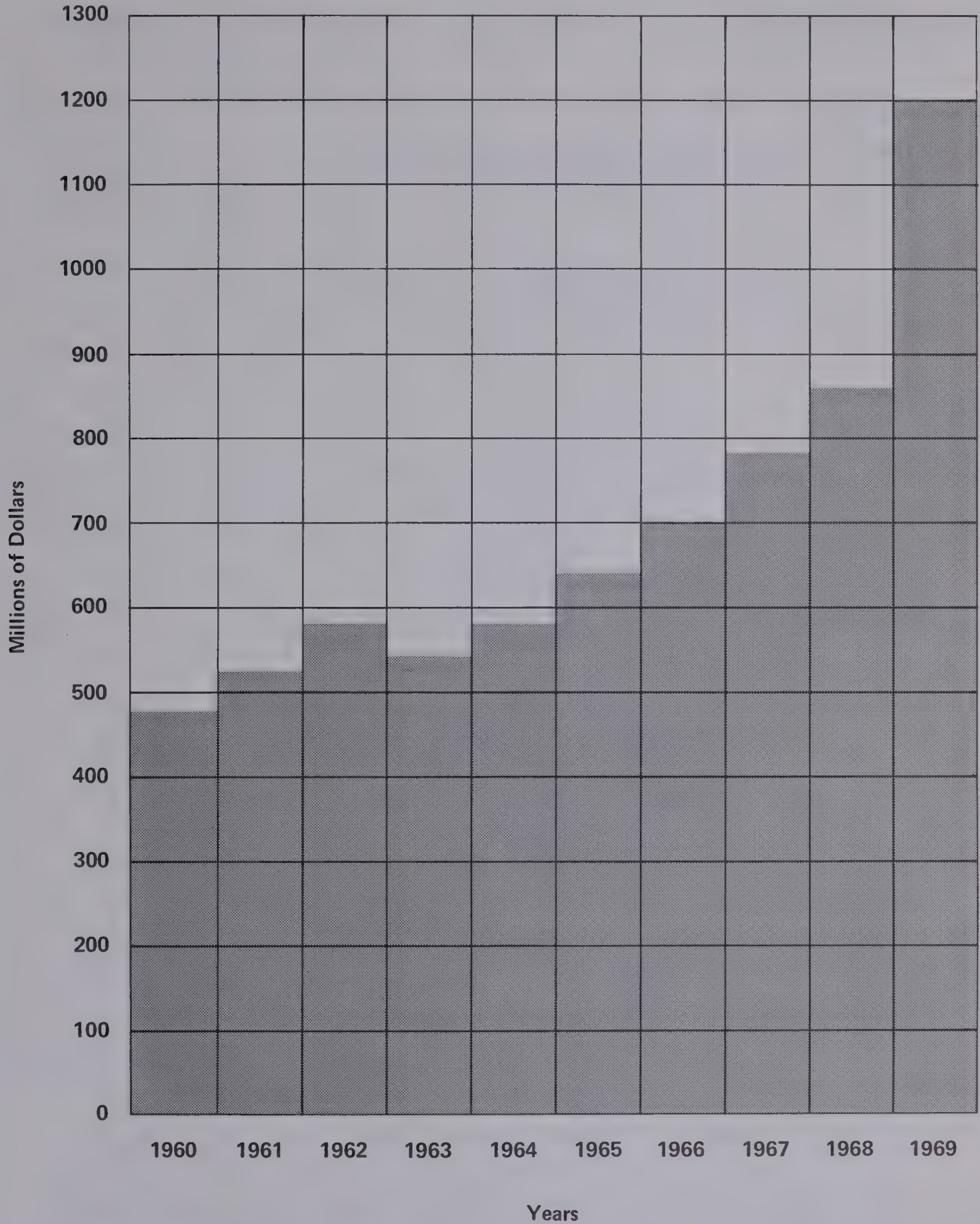
*Language of Graphs:* 16 mm, color or black and white, 13½ min., Coronet Films Cat. No. 190.

## POSSIBLE ANSWERS

1. A graph. (This will need help.)
2. The title.
3. Numbers and labels (What it's all about, etc.).
4. Evenly, the spaces are equal, etc.
5. Professional and technical workers.
6. You only had to see which pair of bars had the biggest difference.
7. Around 1940. (Note that according to the graph, 1940 is the year when there were the least number of children *under five,* and not the year in which there were the fewest births. It is reasonable to expect, though, that the year of fewest births is near this year. We suggest you take this question in a straightforward manner; avoid getting involved in the subtleties.)
8. You only had to see where the line was lowest.
9. 1969.
10. 1960.
11. 1966.
12. 720 million dollars (1,200 minus 480 = $720 million).
13. Going up.

GRAPH NO. 3

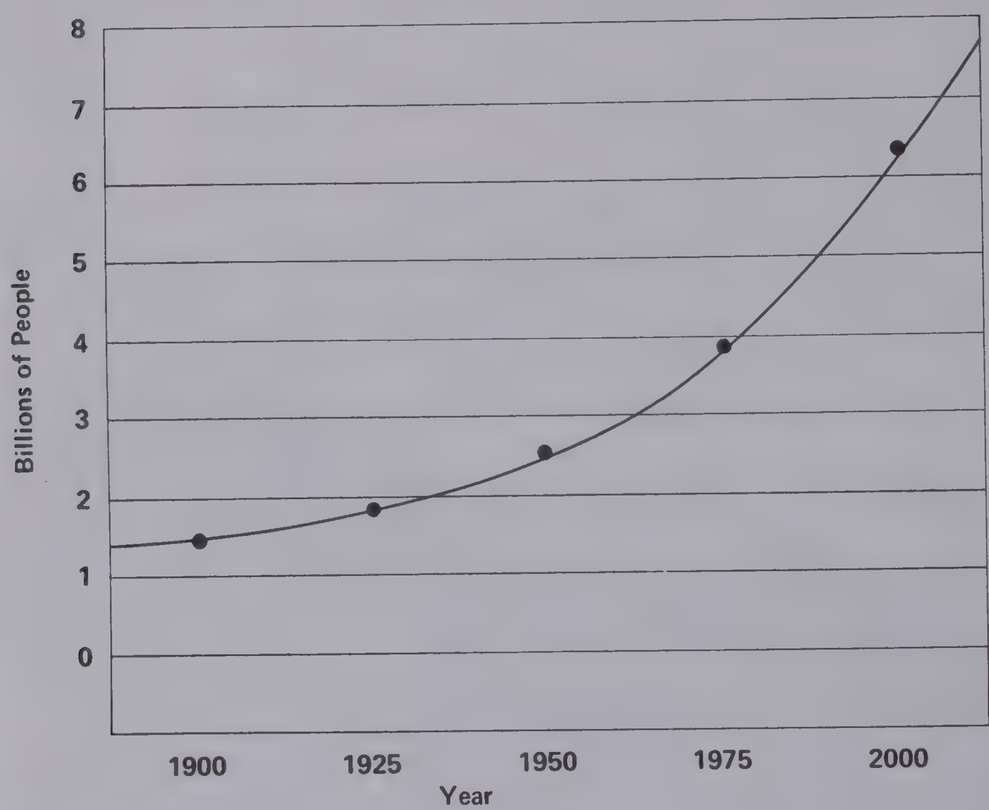
TOTAL YEARLY SALES OF PHONOGRAPH RECORDS IN U.S.A.



14. 1967 to 1969.
15. 5 points.
16. Connect the points with a smooth (curved) line.
17. About 3.0 billions.
18. About 11 billions.

### GRAPH NO. 4

**THE GROWTH IN WORLD POPULATION (past and projected)**

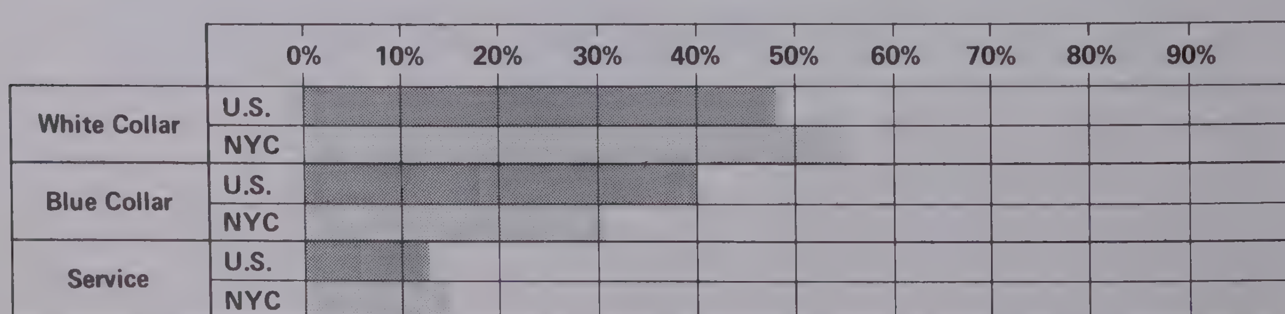



19. White collar.
20. Get as much education as he can.
21. Graphs make information easier to understand, show the important part rather than details, and let you predict what may happen next.

**CONCEPT SUMMARY**: Graphs make information easier to understand.

### GRAPH NO. 5

**TYPES OF JOBS IN THE U. S. AND NEW YORK CITY (percent of jobs)**



## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 10 (2 periods)

**PURPOSE**: Show how conclusions are based upon data.

**DEVELOPMENT**: A question about rolling balls will be answered by an experiment designed and performed by the student.

While scientific knowledge and technology are familiar to students, it is the discovery process itself which is most important.

**HIGHLIGHT**: The student answers his question with data he collects himself (part A, pages 35 & 36).

**MATERIALS** (for each team of two)

Ball set used in Investigation 1.
Wood, 1" x 4" x 2 feet long or longer (alternatively: plastic, corrugated roofing)
Ruler, 12" metric, to serve as ball guides on the wood incline–2 are needed

**MATERIALS** (for each class)

Clock with second hand, or metronome.

**TEACHING TIPS**

**Responses to Expect**: When left to their own devices, students tend to feel insecure, and many will want you to give more explicit directions. You can expect many questions from them, and in replying you can give the Socratic method a vigorous workout.

Ask, "How do you know X is so?" instead of saying, "See if X is so by trying . . . . " Ask, "How many trials are you going to make? Why?" instead of saying, "You had better make several trials so that you can be sure . . . " When a student asks, "Should I do . . . . ? " you might reply, "Do you have any ideas about this yourself?" If he says he has no ideas, give him a hint, but in the form of a question.

The point, of course, is that you are encouraging the students to use what they know, instead of passively going through prescribed, meaningless procedures. In the process of asking questions of individuals or lab teams, outline the experiment when necessary.

It is important for the teacher to realize that frequently a questioning student is really seeking assurance rather than an answer. Already having answered his own question, he may merely be trying to evaluate his own views by getting yours. Or he may be simply exploring your feelings toward him. He is wondering if it is safe in the interests of learning to expose his weaknesses to you. Therefore, apply the Socratic method in a way that gives students the assurance and self-confidence they need.

**Practical Hints**: See that much of the experiment is committed to paper before the materials are distributed. Otherwise, there will be too much aimless activity.

Depending on how much the balls roll down the incline and how much they slide down, there may be differences among hollow and solid balls. If this occurs, use it to show that conclusions must come from data, not from predictions. Expand this by asking if the same thing is true of everyday living.

Have some scientific journals in the room. If you can't get more than *Science* from your local library or the nearest community college, ask your doctor for a few copies of the A. M. A. Journal.

**Discussion and Review**: This investigation has reinforced the whole discovery process discussed throughout the unit. The culmination of the student's activity here is to use his data to decide whether something is or is not so.

Science can be thought of as both a storehouse of information and a discovery process. It is the process we want to stress here.

## ENRICHMENT

Some students may want to plan experiments to answer questions of immediate and practical interest—questions involving future education, job occupations, car buying, etc.

You may have a panel or debate on whether this method can be applied to social problems.

## REFERENCES

### Books

Blanc, S. S., A. S. Fischler, and O. Gardner, *Modern Science: Forces, Change, and the Universe.* New York: Holt, Rinehart, & Winston, 1967. Pp. 20-23.

Journals of the various societies, e.g. Physics, Chemistry, Acoustics, etc.:

*Monthly Labor Review.* U.S. Department of Labor.

### Multi-Media Aids

*Galileo:* 16 mm, color or black and white, 13½ min., Coronet Films Cat. No. 1172.

## POSSIBLE ANSWERS

### The Experiment

*Problem:* We are trying to find out if balls that bounce higher roll faster. (*Or* "balls that are larger roll faster." *Or,* " . . . balls that are harder roll faster." Etc.)

*Materials Used:*

Ball set of Investigation 1
Wood board, 2 ft x 4" x 1"
Meter sticks for ball tracks—2 are needed
Some kind of timer (metronome, flasher, clicker, etc.)

*Procedure:* In students' own words.

1. Each ball will be rolled down the same distance.
2. The time will be measured by counting ticks (or clicks, flashes, etc.).
3. Each ball will be run several times.
4. The times will be in a data table with an average for each ball.
5. The averages will be put on a graph.

*Results:* The table and graph as constructed by the students. There probably will be little difference among the balls, depending on the smoothness of the board and whether the balls slide or roll.

*Conclusion:* This will depend upon the data. If the balls were truly rolling; the hollow balls might be slower. In any event, the conclusion should follow each student's data. This is the key point.

### Answers to Questions

1. The data collected in the experiment.

2. Science is the activity of learning about the universe. It is the activity of testing predictions, gathering data, and putting the information together.

3. Experiments are reported in writing. The data are organized in tables and graphs. The scientist draws his conclusions. The report is published so other scientists can check the results and experiment further.

**CONCEPT SUMMARY**: Conclusions are based on the data from scientific experiments.

## PHYSICAL SCIENCE IDEA 1: PREDICTING, Investigation 11 (1-2 periods)

**PURPOSE**: Pull together the unit by presenting its major idea: Science is the activity of finding out.

**DEVELOPMENT**: (A) Students tied together by string will try to figure out how to separate themselves without cutting the string or untying the knots, and the steps they use to solve this problem will be related to the scientific discovery process.

(B) Using data on sound intensities, students will offer a solution to a problem they encounter in their everyday lives.

**HIGHLIGHT**: The steps in getting loose do follow the steps outlined in part A.

**MATERIALS** (for each team of two)

String, about one yard, 2 pieces

**MATERIALS** (for each class)

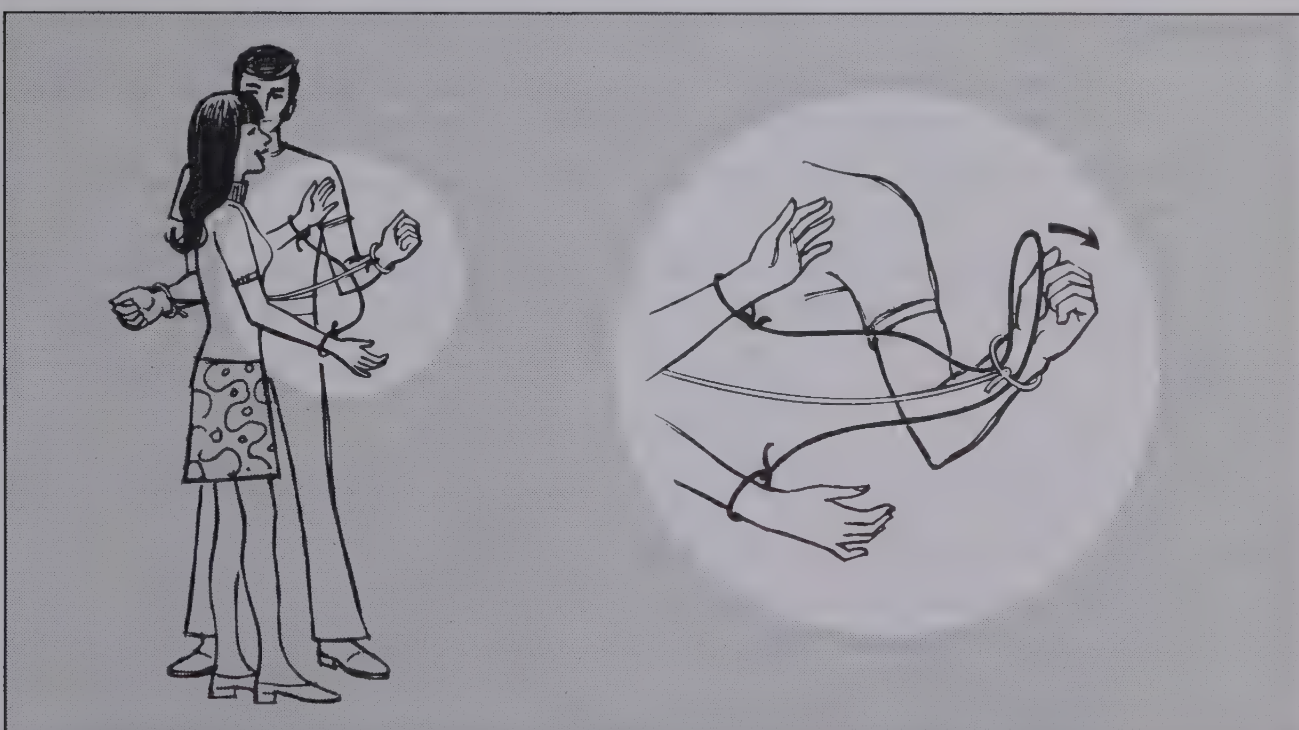
Magazines and journals with articles about sound levels and hearing

**TEACHING TIPS**

**Responses to Expect:** Students may ask, "Can we use this system for other problems?" Usually the answer is yes. But it is harder to get data on people than it is on things, and therefore it is more difficult to find solutions to social problems.

Students may ask questions about sound and sound intensity measurement. It may be better not to get into it too deeply, but here is some information of general interest. Any object that vibrates within the range of about 16 vibrations per second up to about 18,000 vibrations per second will emit air waves that can be detected by the human ear as sound. This range decreases as one gets older. The human ear is most sensitive about 3,000 vibrations per second.

The decibel sound intensity scale was designed so that one decibel would be the smallest change in sound intensity that the human ear could detect. A three decibel increase represents a doubling of sound energy. Check the decibel scale given in the text on page 40 for an understanding of the scale's meaning.



**Practical Hints**: Part A: to get loose, pass a loop from one student's string through the wrist loop and over the hand of the other student.

If students say they are not worried about hearing problems, ask them what they will do when the fads change and low sound is the in-thing. Don't expect much response; for them, the only time is now.

**Discussion and Review**: This investigation is the wrap-up of the unit. Here we want to conclude the idea that science is the activity of people interested in their surroundings.

Science is a part of the human endeavor. The doctor in Florida measuring the sound level of a musical rock-band was not a disinterested observer or a killjoy; he was a father concerned about his daughter's hearing.

Spend some time asking what are the normal activities of the students' everyday lives that science affects. Their transportation to school, their food, light, heat, and electricity are from a technology born of science. If you must, in order to stimulate discussion, say something atrocious that you know will be challenged.

Scientists are involved. They are taking sides on civil rights and such issues as the ABM and the use of DDT. Use some of these issues, or what is current, to show that science is not cut-and-dried facts.


## ENRICHMENT

Some students may pursue the noise and hearing problem further. Local hi-fi outlets may help them with information about the sound output of various electrically amplified instruments.

See if the school has equipment to test hearing. Have the nurse or whoever is qualified demonstrate and explain the equipment.

Have some students demonstrate the range of hearing with an audio signal generator and amplifier speaker system. Let the members of the class find out how high a frequency they can hear. The variation will be a surprise.

## REFERENCES

### Books and Articles


Davis, I. C., J. Burnett, E. W. Gross, and T. D. Johnson, *Science: Discovery and Progress.* New York: Holt, Rinehart, & Winston, 1965. Pp. 1-17.

"Does Rock Music Damage Hearing?" *Good Housekeeping,* April, 1969. Page 208.

"Noise Takes Toll, Say Experts," *Today's Health,* October, 1967. Page 87.

Pella, Milton O., *Physical Science for Progress* (3rd ed.). Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970. Pp. 1-6, 25-26, 463-464, 471-474.

"Rock Physically Unsound," *Science Digest,* June, 1968. Page 87.

"Vibrations, Noise Inhibits Muscles," *Science News,* March 8, 1969. Page 239.

**Multi-Media Aids**

*Aristotle and the Scientific Method:* 16 mm, color or black and white, 13½ min., Coronet Films Cat. No. 1169.

**POSSIBLE ANSWERS**

1. The problem.
2. The prediction.
3. The experiment.
4. The data.
5. The conclusion.
6. Damage to ear begins.
7. It might damage hearing.
8. (Let each student decide his answer. Encourage the why of his answer. Never mind which course he chooses; see how he gets there.)
9. They are more likely to reach conclusions based on facts rather than emotions.

**CONCEPT SUMMARY:** The scientific method can help in solving everyday problems.

**IDEA SUMMARY:** Science is an attitude, a method, an activity of man interested in finding out more about his natural environment.

# Idea 2
## Matter

Idea 1 has given your students the rationale of science. Idea 2, a series of eleven investigations may be summarized as:

THE UNIVERSE IS MADE OF MATTER AND ALL MATTER IS MADE OF TINY PARTICLES.

Remember, this is not a pronouncement to be memorized word for word. Ideas may take many forms, and students should be encouraged to state concepts and ideas in their own words.

The first few investigations define matter and consider its properties. Then permanence of matter is demonstrated during both physical and chemical changes. In Investigation 6, students are given simple evidence for the particulate nature of matter. The next three investigations reinforce this evidence and lead to the idea that all matter consists of various combinations of the same elemental building blocks. Finally in the last two investigations the student finds that the elemental building blocks are made of still smaller entities.

Reread the whole Idea before starting. Remember when scheduling preparation time that equipment is more specialized than in Idea 1 and some activities will overlap. The Teachers Manual will give you advance notice of these activities at the appropriate times.

## PHYSICAL SCIENCE: IDEA TWO (MATTER)

### The Universe Is Composed of Matter and All Matter Is Made of Tiny Particles

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. THAT'S ABOUT THE SIZE OF IT | All matter has the properties of weight and volume. | Weighing and measuring various objects |
| 2. JUST HOW MUCH IS IN THAT BAG? | Density is the ratio of weight and volume. | Computing density from weight and volume |
| 3. TIME FOR A THAW | The total amount of matter present remains the same whether it takes the form of a solid, liquid, or gas. | Weighing ice and water |
| 4. A ROSE BY ANY OTHER NAME | The amount of matter remains constant during a change of state. | Weighing and melting sulfur |
| 5. SOMEHOW IT'S NOT THE SAME | The total amount of matter present remains the same during a chemical change. | Weighing substances before and after a chemical change |
| 6. ONE AND ONE DON'T MAKE TWO? | Matter acts as though it is made of particles. | Measuring volume of solutions and mixtures |
| 7. IT'S A GAS | Matter reacts in constant proportions. | Measuring products of reaction of magnesium and hydrochloric acid |
| 8. LET'S BREAK SOMETHING | Matter breaks up in constant proportions. | Electrolysis of water |
| 9. DON'T GO TO PIECES | Matter is composed of different elements, each consisting of atoms. | Heating mercuric oxide; decomposing sodium peroxide in sulfuric acid |
| 10. WHAT GOES ON IN THERE? | Atoms contain smaller particles. | Static electricity; electroscope; Geiger counter; graphing radioactive decay |
| 11. MAKE YOUR OWN PIECES | Atoms are made up of protons, neutrons, and electrons. | Knocking marbles out of a circle |

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 1 (1½-2 periods)

**PURPOSE**: Develop the concept that matter is everything that has weight and volume.

**DEVELOPMENT**: (A) Students will examine various materials and will find that they all have weight and volume. As a lab activity they will make measurements of (B) weight and (C) volume.

Weight and volume will be used to describe the tangible substances of our surroundings.

**HIGHLIGHT**: In addition to other properties, such as color, shape, or hardness, all objects have volume and weight (No. 2, page 42).

**MATERIALS** (for each team of two)

*Part A–Matter has weight and volume*
Miscellaneous objects, 15 to 60 ml volumes–6 to 9 objects needed. (These objects must be small enough to fit into a graduated cylinder and must be immersible in water.) For example:

- stone
- hardwood block
- iron block
- aluminum block
- metal cylinder
- rubber block
- piece of brick
- piece of dowel
- gum eraser

*Part B–Weight*

Balance, platform

*Part C–Volume*
Cylinder, graduated, 100 ml
Paper clip, jumbo size: 2" long (used to push floating objects beneath the water line)
Ruler, 12" metric
Thread, 12"
Ball, white, styrofoam, 3" dia.
Ball, white, rubber, 3" dia.

**MATERIALS** (for the teacher–see Practical Hints)

**Preparation of Materials**

The miscellaneous objects should be assembled in a container. A plastic tray, shoe box, or whatever will do. Distribution of materials in class will be simplified if a tray is made up for each team prior to each investigation.

**TEACHING TIPS**

**Responses to Expect**: Some may ask, "What's a milliliter?" Be prepared to review metric units.

"Why does the water line curve in the graduated cylinder?" Explanation: Water sticks to the glass around the edges but there is nothing to hold it up on the center.

**Practical Hints**: To start students listing properties, hold up a 3" white rubber ball and a 3" white styrofoam ball. Squeeze the rubber to deform it and ask, "What is different?"

A piece of wire (straightened, jumbo size paper clip) will push floating objects under water.

**Discussion and Review**: The starting point of this series is the notion that everything is made of something. The student is to start becoming aware of the myriad materials that surround him. Then the nature of these materials can be investigated.

## ENRICHMENT

1. Have a student explain or demonstrate how to prove or disprove that air is matter.
2. Challenge curious students with questions about the weight of a gas in a balloon that rises.

## REFERENCES

### Books

Davis, Burnett, Gross, & Johnson, *Science, Discovery and Progress.* New York: Holt, Rinehart, & Winston, Inc. 1965.

Quagliano, James V., and Lidia Vallarino, *Chemistry,* 3rd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969.

### Multi-Media Aids

*Archimedes' Principle:* 8 mm film loop, color, 2 1/4 min., Ealing Cat. No. 82-0027.

## POSSIBLE ANSWERS

1. Students' descriptions; e.g. red, rough, smooth, heavy, etc.
2. They all take up space. They all have weight.
3. Yes.
4. Yes.
5. Yes.
6. Yes.
7. Light, heat (Some people would maintain that only concrete objects may be admitted to the category of *things,* but in common speech *thing* often refers to abstractions such as *idea* or *notion,* as in "first *thing* that comes into his head." If you accept this broader interpretation of *thing,* then there are *many things* in the world that do not both have weight and occupy space. It comes down to a matter of definition. Most dictionaries give both definitions.)
8. Matter.
9. Students' data.
10. Volume.
11. It would rise. The object takes up the space and pushes the water aside.
12. One or two ml depending upon the graduate used.
13. Students' data.
14. Subtract the first reading from the second.
15. Students' data–various volumes.
16. Matter.

**CONCEPT SUMMARY**: Almost everything is made of matter. All matter has weight and volume.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 2 (2 periods)

**PURPOSE**: Develop the concept of density as the measure of the compactness of matter.

**DEVELOPMENT**: Volumes of solids and liquids will be compared with their weights.

This ratio of weight to volume is found to be an intrinsic property of matter, useful in identifying substances.

**HIGHLIGHTS**: The weights of the identical appearing blocks differ widely (No. 7, page 46).

Equal volumes of identically colored liquids weigh different amounts (No. 13, page 48).

**MATERIALS** (for each team of two)

*Part A–Density of solids*

1 1/2 cm x 1 1/2 cm x 4 cm blocks painted the same color, each material assigned an identifying number

- aluminum
- balsa
- hardwood
- iron
- polyurethane
- rubber

Balance, platform

*Part B–Density of liquids*

Liquid set, 50 ml of the following liquids colored blue to the same tone with ink:

- alcohol, ethyl
- Karo pancake syrup
- Karo & water in a 1:1 ratio
- water

Cylinder, graduated, 100 ml

**MATERIAL** (for the class)

Translucent plastic bottle of aluminum paint (optional)
Translucent plastic bottle of mercury (optional)
(Note: each bottle should be the same size and filled to the same level.)

**Preparation of Materials**

Other solutions may be used in place of the Karo and Karo-water liquids. For example: (1) Copper sulfate solution made by dissolving about 350 g of copper sulfate crystals per liter of water. Heat the liquid to make the crystals dissolve more quickly. (2) Salt solution made by dissolving about 350 g of salt in a liter of water.

Color the solutions blue with ink to match each other. If ink colors fade, a few drops of hydrochloric acid should be added to the bottle of solution. (See: *The Science Teacher.* Vol. 36, No. 4, April, 1969, p. 53.) If lab aids are scarce and preparation time is a problem, have the four liquids in four dispensing bottles at the front of the room. In this case, students discard the liquids when they are through.

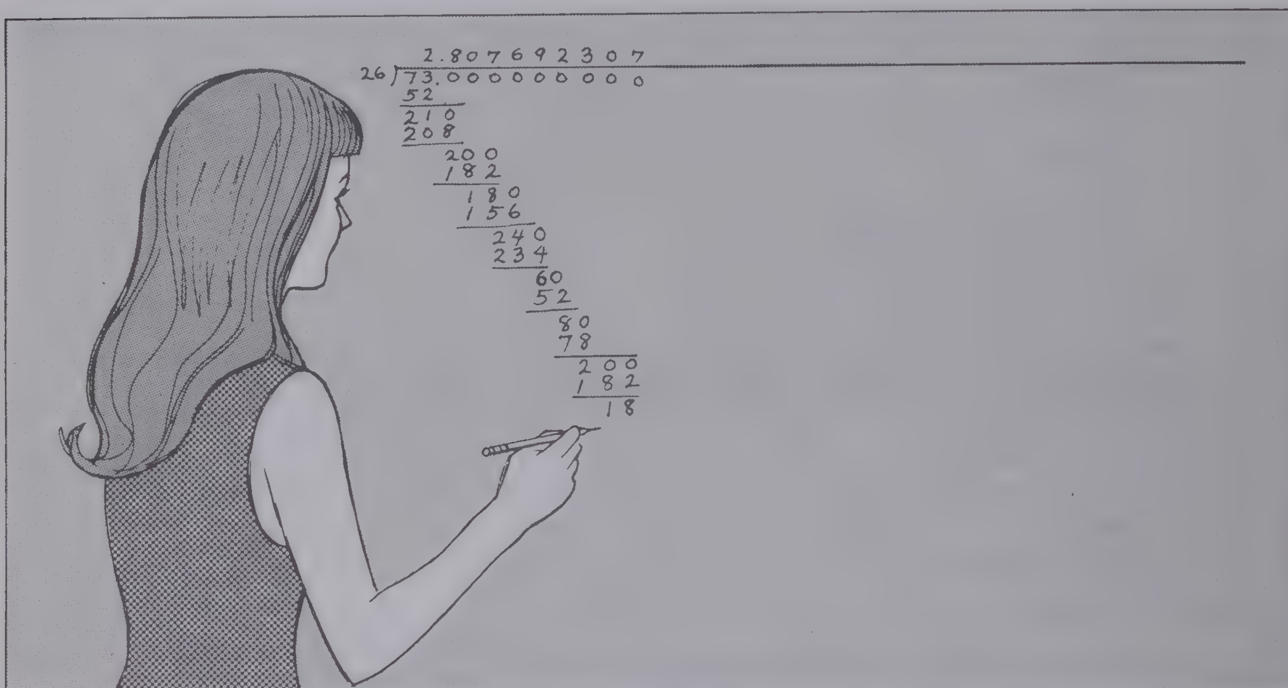
**TEACHING TIPS**

**Responses to Expect**: Students will ask what the various materials are, but this is what the investigation is all about. Therefore, your answer should be part of the theme, "Let's find out." One student convinced his fellows that the liquids were water and food coloring, but was dramatically brought up short by his weight data.

**Practical Hints:** One way to get students interested in density is to hand a bottle of aluminum paint to a student in a front corner seat. Instruct the class to pass the bottle from hand to hand around the room as quickly as possible. When the bottle has traveled about a row, start a bottle of mercury on the same route. The contrast is startling and some students almost drop the bottle. (This is why a plastic bottle is specified.)

Since many students have trouble reading the level of the liquid, you might give them the opportunity to practice: set up three graduates a comfortable distance apart. Have the students file by quickly and record the volumes on a scrap of paper. Read aloud the "correct" volumes. Then ask, "Was your eye too high or too low?" (Do not collect or grade their answers.)

*Be prepared to teach division on the board.* Watch out for the student who can't stop dividing. Get him to round off his answers.




**Discussion and Review:** Avoid density as a sterile something-else-to-be-memorized. It might be more meaningful in terms of why drag racers use magnesium wheels or why aluminum finds its way into kitchen utensils while lead is used for fishing sinkers.

## ENRICHMENT

1. Let some eager and curious student mix the solutions to let the class know what will happen. If he pours alcohol into a salt solution, an interesting "salting out" or precipitation will take place.

2. A student may want to try a layering experiment with liquids of different densities. Liquids having a common interface should be insoluble in each other.

3. Students may look in handbooks or other references for densities of gold, mercury, uranium, or for the densest element.

4. A student interested in astronomy may have heard of the fantastic densities of matter in dwarf stars. The idea of a tiny cube weighing as much as several cars is a tough one to swallow.

## REFERENCES

### Books

*Handbook of Chemistry and Physics.* Cleveland, Ohio: Chemical Rubber Publishing Company.

Stollberg, Robert, and Faith Fitch Hill, *Physics, Fundamentals and Frontiers.* Boston: Houghton Mifflin, 1965.

Blanc, S. S., A. S. Fischler, and O. Gardner, *Modern Science: Forces, Change, and the Universe.* New York: Holt, Rinehart, & Winston, 1967. Pp. 9-11.


**Multi-Media Aids**

*Density of Liquids:* 8 mm film loop, color, 2½ min., Ealing Cat. No. 82-0043/1.
*Identifying Solids by Density:* 8 mm film loop, color, 4 min., Ealing Cat. No. 80-3262/1.
*Identifying Liquids by Density:* 8 mm film loop, color, 4 min., Ealing Cat. No. 80-3270/1.
*Identifying Gases by Density:* 8 mm film loop, color, 4 min., Ealing Cat. No. 80-3288/1.

**POSSIBLE ANSWERS**

1. Yes, they are both quarts.
2. No. Some liquids are "heavier" (more dense) than others.
3. Like a brick.
4. Length, width, and height.
5. Cube. (Hence, volume is cubic. . .)
6. They are all the same.
7. They are different.
8. Some have more matter packed in them than others.
9. Things with the same volumes can have different weights.
10. Grams per cubic centimeter, g/cc.
11. (Answers derive from data.)
12. No. Things can look alike but have different weights.
13. (Answer derives from data.)
14. It has more matter in the same space.
15. Yes. Different substances have different densities but any one substance keeps the same density. (Note: The variations in the densities of liquids and solids due to changes in temperature are small enough that they can be ignored for many purposes.)
16. It took accurate measurements to identify the different kinds of matter.

**CONCEPT SUMMARY**: Density, the ratio of weight to volume, tells the weights of equal volumes of substances. *Or* density tells how tightly matter is packed.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 3 (1-1½ periods)

**PURPOSE**: Snow that the mass of a given specimen of matter doesn't vary as it changes form.

**DEVELOPMENT**: Students will see that a closed container of ice maintains a constant weight when the ice melts and forms water.

The basic principle at heart here is the conservation of matter but it is never made a stuffy formalism to be memorized.

**HIGHLIGHT**: There is no weight-change when the ice melts (No. 5, page 50).

**MATERIALS** (for each team of two)

*Part B–Weighing water, before and after melting*
Test tube, 18mm x 150mm or 50 ml stoppered vial
Rubber stopper, solid, for the test tube above
Balance, platform
Beaker, plastic, 400 ml
Ice, crushed, 45 ml
Water, 60$^{\circ}$ C or hotter, 300 ml
Paper towels–about 2 are needed

**Preparation of Materials**

Crushed ice may be prepared by wrapping ice cubes in a rag or paper towels and applying a hammer. One large tray or two small trays of cubes will supply an average class.

If your room does not have hot water piped in, heat 3 or 4 liters of water to about 60$^{\circ}$ in advance.

**TEACHING TIPS**

**Responses to Expect**: Some students will know that water expands when it freezes. They will reason that if the ice melts and takes less room as water, it should weigh less. Counter this kind of question with the concept of density. Ice floats because it is less dense.

Be prepared to demonstrate for students the constant volumes of liquids by having a beaker, an Erlenmeyer flask, and a Florence flask all of the same size ready. Show by pouring water from one to another that the same amount fills them all.

**Practical Hints**: Introduce the concept of solids, liquids, and gases by first dropping something solid, then spilling a small amount of liquid on the table. Ask how their behavior was different. Use a balloon for the gas and squeeze it to show that shape and volume change. Do not comment when squeezing the balloon; just ask what is changing.

After students have melted their ice in warm water, be sure they dry the outside of the test tube thoroughly. Water of condensation is one problem when weighing ice. Failing to wipe off the tube completely after melting the ice is another.

Some students have trouble with the test tube rolling off the balance pan. Standing the tube inverted on the broad surface of the stopper may be the lesser of evils here.

If the weights and rider of the balance are not disturbed during the melting procedure, it is more dramatic when students put the test tube back and find the weight unchanged.

**Discussion and Review**: When discussing the three states of matter, challenge the students to come up with matter that doesn't fit one of the categories. Plasmas and solids flowing under pressure are two possibilities.

Ask if a sealed container will weigh the same amount in a week, a month, or a year. Then see if students are convinced that matter has permanency.

Wind up with a question about whether other materials will act the way water did. This could be used as introduction to the next investigation with sulfur.

## ENRICHMENT

A sharper student may want to read or report about plasma as a fourth state of matter.

Get someone started on the fact that a rock placed on an open barrel of tar often will gradually disappear. What form of matter is the tar?

Have some student do the reverse investigation using a salt and ice mixture to freeze the water in the test tube. Naturally use a refrigerator freezer, if you have one.

## REFERENCES

### Multi-Media Aids

*Solids, Liquids, and Gases:* 16 mm, 8 min., McGraw-Hill.

*Plasma: the Fourth State of Matter:* 16 mm, color, 9 3/4 min., Film Associates Cat. No. 16-281.


## POSSIBLE ANSWERS

1. A solid keeps its shape. A liquid takes the shape of its container.
2. A liquid keeps its volume. A gas takes the volume of its container.
3. Solid, liquid, and gas.
4. Students' predictions, such as "It will be lighter, the same, heavier."
5. Zero (or almost zero).
6. Zero (or almost zero).
7. No. If the weight didn't change, the amount of matter could not have changed.
8. It stays the same.

## CONCEPT SUMMARY:

A. Matter takes three forms: solid, liquid, and gas.

B. The amount of matter present stays the same when it changes from solid to liquid.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 4 (1-1½ periods)

**PURPOSE**: Reinforce the idea that the quantity of matter remains constant when its form changes.

**DEVELOPMENT**: (A & B) Students will see that a closed container of sulfur maintains a constant weight as the sulfur is melted and solidified, and as it is vaporized and condensed.

The underlying basic principle is the conservation of matter, but it is handled here in simple terms.

**HIGHLIGHT**: There is no weight-change when the sulfur melts and resolidifies (No. 3, page 52).

**MATERIALS** (for each team of two)

*Part A–Melting and crystalizing sulfur*
Test tube, Pyrex, 18 mm x 150 mm
Balloon, to fit over mouth of the test tube
Sulfur, powdered, 10 ml
Clamp, test tube (or burette clamp)
Burner
Goggles, safety (if you already have them)

**TEACHING TIPS**

**Responses to Expect**: Many students will be puzzled about how they can recognize when the sulfur is completely melted, and when it is completely solidified. You can usually demonstrate sulfur's liquidity by tipping the tube. Use some simple rule of thumb, such as the tube being cool enough to handle, for deciding when it has hardened.

**Practical Hints**: Make sure that students don't overheat the sulfur. Sulfur exists in several forms. When it first melts it is a free running liquid. Heating it further will convert it to a viscous form that flows very slowly.

It is economical of time and materials to discard the test tubes. Students find it difficult to understand that cleaning the tubes may be more expensive than discarding them and replacing them with new ones. So that they don't interpret discarding the tubes as a license to be wasteful, it may be better to throw them out in a place where students won't come upon them.

**Discussion and Review**: Emphasize that students now know of two materials that don't change quantity with change of form. Ask for confidence that it will hold for other substances.

**ENRICHMENT**

Repeat the lab with other materials, such as a small beaker of wax, or something more common, as shortening or olive oil. The latter will solidify at refrigerator temperatures.

Have a student pour heated liquid sulfur into cold water. A rubbery form of sulfur will result which gradually hardens and reverts to the usual solid.

Give an interested student the problem of a piece of ice floating in a container of water. Have him predict the water level when the ice melts. It will be the same, but the arguments in advance may prove revealing about the student's view of the world of matter.

**REFERENCES**


**Books**

Quagliano, James V., and Lidia Vallarino, *Chemistry*, 3rd ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969.

**Multi-Media Aids**

*Sulfur and Its Compounds:* 16 mm, color or black and white, 13 1/2 min., Coronet Films Cat. No. 1436.
*Sulfur and Hydrogen Sulfide:* 16 mm, color or black and white, 21 min., Coronet Films Cat. No. 1366.

**POSSIBLE ANSWERS**

1. Tiny droplets or crystals of sulfur.
2. A gas.
3. None (or almost none).
4. None. The weight did not change.
5. No, because the weight didn't change.
6. It agrees, since the amounts did not change.
7. The heat made some of the solid sulfur evaporate.
8. The amount of matter stays the same regardless of what form it takes.
9. Yes. Two substances gave the same result, and we believe nature is consistent.

**CONCEPT SUMMARY:** The amount of matter stays the same regardless of how it changes form.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 5 (1-1½ periods)

**PURPOSE**: Extend the idea of the constant amount of matter to the case of a chemical change.

**DEVELOPMENT**: (A & B) A container of sodium carbonate solution will have lowered into it a container of phenolphthalein. Students will find that the weight of these chemicals, after they are mixed and react, is the same as it was before.

**HIGHLIGHT**: The weight remains constant when the phenolphthalein and sodium carbonate solutions react (No. 7, page 54).

**MATERIALS** (for each team of two)

*Part A–Reaction of sodium carbonate and phenolphthalein*
Sodium carbonate solution, 10 ml (Liquid 1)
Phenolphthalein solution, 10 ml (Liquid 2)
Vial, plastic, 11 ml (Alternately: 13 mm x 100 mm Pyrex test tube or culture tube)
Vial, plastic, 25 ml with watertight lid (Alternately: stoppered 250 ml Erlenmeyer flask)
Balance, platform
Funnel
Paper towels–1 or 2 are needed
Beaker, 100 ml Pyrex

**Preparation of Materials**

Liquid 1, sodium carbonate solution: Dissolve 20 to 30 g of sodium carbonate powder or crystals in water, and dilute to 1 liter. This is sufficient for 5 classes of 30 students.

Liquid 2, phenolphthalein solution: A ½% to 1% solution will give satisfactory results. This can be ordered directly from chemical supply houses, or made up yourself as follows: Dissolve about 5 g solid phenolphthalein in 700 ml ethyl alcohol; dilute with water to 1 liter. This is sufficient for 5 classes of 30 students each.

Put a bottle of each liquid at a convenient location, each liquid separated by some distance to minimize crowding. Avoid excessively large bottles so that students will be able to pour easily.

**TEACHING TIPS**

**Responses to Expect**: Questions will center about the chemicals. What are they? Are they poisonous? What will happen if I drink some? Have students start a practice of washing their hands after any lab session where they have handled chemicals.

**WARNING**: CHEMICALS ARE FREQUENTLY POISONOUS WHEN TAKEN INTERNALLY, AND IN SOME CASES WHEN ABSORBED THROUGH THE SKIN. STUDENTS SHOULD THEREFORE KEEP CHEMICALS AWAY FROM THEIR MOUTHS, AND SHOULD WASH THEIR HANDS AFTER HANDLING THEM.

**Practical Hints**:Demonstrate how to lower the smaller container into the larger without spilling any liquid.

If a group's data is at variance with the rest of the class, don't make them conspicuous. Ask privately if they can explain the difference; let them volunteer remarks about sloppy measurements or goofs; and have compassion rather than criticism. If time permits, let them repeat the lab work.

**Discussion and Review**: Don't start the general discussion until all of the teams have their data on the board.

Go through the reasoning slowly. The change of properties indicates a change in the kind of matter. You can introduce the phrase "chemical change" in your discussion. It's handy, as long as it is not another phrase to be laboriously memorized.

Lead the class into agreement that unchanging weight again means an unchanged amount of matter. Wonder aloud if this conclusion would have given the early scientists confidence in their measurements and results.

## ENRICHMENT

An interested reader could look up Lavoisier's original work with sealed reactions.

The investigation may be repeated with other materials; silver nitrate and sodium chloride or manganese chloride and oxalic acid solution are possibilities. Lead nitrate solution and sulfuric acid would also work but is hazardous.

An ingenious student can be given the problem of performing the experiment with a combustible reaction. He will have to decide how to keep from losing reaction products.

## REFERENCES

### Books and Articles

Cable, E.J., W.R. Getchell, W.H. Kadesch, Willard J. Poppy, and Leland W. Wilson, *The Physical Sciences.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1969. Pp. 72-73.

### Multi-Media Aids

*Laws of Conservation of Energy and Matter:* 16 mm, color or black and white, 8 min., Coronet Films Cat. No. 911.

*Combustion: an Introduction to Chemical Change:* 16mm, 16 min., Film Associates.

*Conservation of Mass:* Film loop, color, 4 min., Ealing Cat. No. 80-3254/1.

## POSSIBLE ANSWERS

1. (The predictions are limited to three possibilities: *greater, lesser, no change.* Probably the majority will predict *no change* on the basis of the two previous investigations.)
2. When the liquids mix, a red solution is formed.
3. Like water.
4. Like water.
5. The solution changed from colorless to red.
6. Yes. The color has changed.
7. They all show no weight change, or very little.
8. No.
9. (Answers will vary with the prediction.)
10. Whether matter is changing form or combining with other substances, the total amount remains the same.

**CONCEPT SUMMARY**: The total amount of matter remains the same when it forms new substances.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 6 (2 periods)

**PURPOSE**: Introduce the notion that matter is made of particles.

**DEVELOPMENT**: (A) When students mix salt and water, the final volume will be less than the sum of the two elements before mixing. (B) Mixing Puffed Rice and popcorn will produce the same result.

One way of explaining these anomalies is to assume that matter consists of particles.

**HIGHLIGHTS**: The water level in the salt and water mixture is lower after shaking (No. 6, page 56).

The total volume of popcorn and Puffed Rice is less than the sum of the original volumes (No. 11, page 58).

**MATERIALS** (for each team of two)

*Part A–Mixing rock salt and water*
Rock salt, 140 ml
Cylinder, graduated, 100 ml–2 are needed
Stoppers, rubber, solid, for the graduated cylinders–2 are needed
Tape, masking, 2" (used as a label)

*Part B–Mixing popcorn and Puffed Rice*
Beaker, 250 ml
Jar, wide mouth, 1 quart
Popcorn, 250 ml
Puffed Rice, 250 ml
Tape, masking, 1" (used to mark volume)

**Preparation of Materials**

In parts A and B students can carry solids to their stations on pieces of paper. So that students can judge the quantity to pour out, place by each stock bottle on a piece of paper the amount of the solid they will need.

**TEACHING TIPS**

**Practical Hints**: Make sure that the measurements with the popcorn and Puffed Rice cereal are made before the supply begins to disappear.

Keep a broom and dustpan in the room. Don't make sweeping up a punishment, just some straightening up after the "party."

Ask the class if a beaker of marbles is full. When they agree, pour in a handful of B-Bs or small shot.

**Discussion and Review**: Discussion will revolve around forming a picture, or model, of matter that will fit the data. Is it easier to explain the data if matter comes in particles? Try to lead the class to proposing that viewpoint.

Ask dissenters for a picture of matter that fits the data but does not make use of particles. Decide which explanation is easier to make.

**ENRICHMENT**

The readers in the group may look for works on Dalton or even Democritus.

Have some students start a diffusion experiment with a copper sulfate solution layer at the bottom of a graduated cylinder of water.

Let a student repeat the salt and water part with sand. Does the level change this time?

## REFERENCES

### Books and Articles

Kaplan, Irving, *Nuclear Physics,* 2nd ed. Reading, Mass: Addison-Wesley Publishing Co., Inc., 1963. Ch. 1, Pp. 3-17.

Holton, Gerald, and Duane D.H. Roller, *Foundations of Modern Physical Science.* Reading, Mass.: Addison-Wesley Publishing Co., Inc., 1958. Ch. 16.

### Multi-Media Aids

*Diffusion:* Film loop, color, 3 min., Ealing Cat. No. 80-2959/1.

*Explaining Matter: Molecules in Motion:* 16 mm, color or black and white, 11 min., E.B.F. film number 1746.

*Evidence for Molecules and Atoms:* 16 mm, color or black and white, 19 min., E.B.F. film number 1886.

*Molecular Theory of Matter:* (2nd Ed.), 16 mm, color or black and white, 11 min., E.B.F. film number 2227.

## POSSIBLE ANSWERS

1. It is lower (by several ml).
2. Students' predictions. (Most will predict it will drop.)
3. It is lower.
4. Students' answers. (A greater number usually choose particles.)
5. Yes (or almost).
6. The contents are lower.
7. Slip in or fit between each other.
8. The salt and water particles could fit together.
9. The particle idea.

**CONCEPT SUMMARY**: Different kinds of matter fit together as though they were made of particles.


Each team should have a strip of magnesium ribbon of a different length.

**PURPOSE**: Introduce the idea that substances react in constant proportions.

**DEVELOPMENT**: Magnesium ribbon is reacted with hydrochloric acid to form hydrogen. Comparisons of ribbon lengths to resulting gas volumes show a constant ratio.

This result can be easily explained in terms of particles that fit together and therefore suggests an atomic picture of matter.

**HIGHLIGHTS**: The graph of ribbon length versus gas volume seems to be a straight line (No. 3, page 61).

The ratios of gas to ribbon are all about the same (No. 4, page 61).

**MATERIALS** (for each team of two)

*Part A–Reacting magnesium ribbon with dilute hydrochloric acid*
Magnesium ribbon, between 3 and 10 cm long
Hydrochloric acid, dilute, 100 ml
Ruler, 12" metric
Cylinder, graduated, 100-ml
Beaker, 250 ml
Goggles, safety (if available)

**Preparation of Materials**

Cut pieces of magnesium ribbon in varying lengths: 3 cm, 4 cm, 5 cm, etc., up to 10 cm. Have an extra supply on hand; there will be repeats necessary. To dispense the pieces of ribbon conveniently, stick them by one end to a piece of masking tape, sorted by lengths, so you can pull off the one you want easily. Expect about 7 ml of hydrogen per cm of ribbon.

To prepare the acid, add 130 ml of concentrated acid to 870 ml of water for each liter. Precise accuracy is not critical, roughly one part of acid to seven parts of water will do. The concentrated acid will dissolve synthetic fabrics, so wear an apron or lab coat.

Toward the end of the reaction, when most of the magnesium has reacted, bubbles of hydrogen sometimes float the magnesium ribbon to the surface. If the ribbon sticks to the cylinder walls, it will not completely react. You can prevent this by first tying a thread to the ribbon. The free end of the ribbon passes between the edge of the cylinder and the bottom of the beaker, thereby holding the ribbon in place.

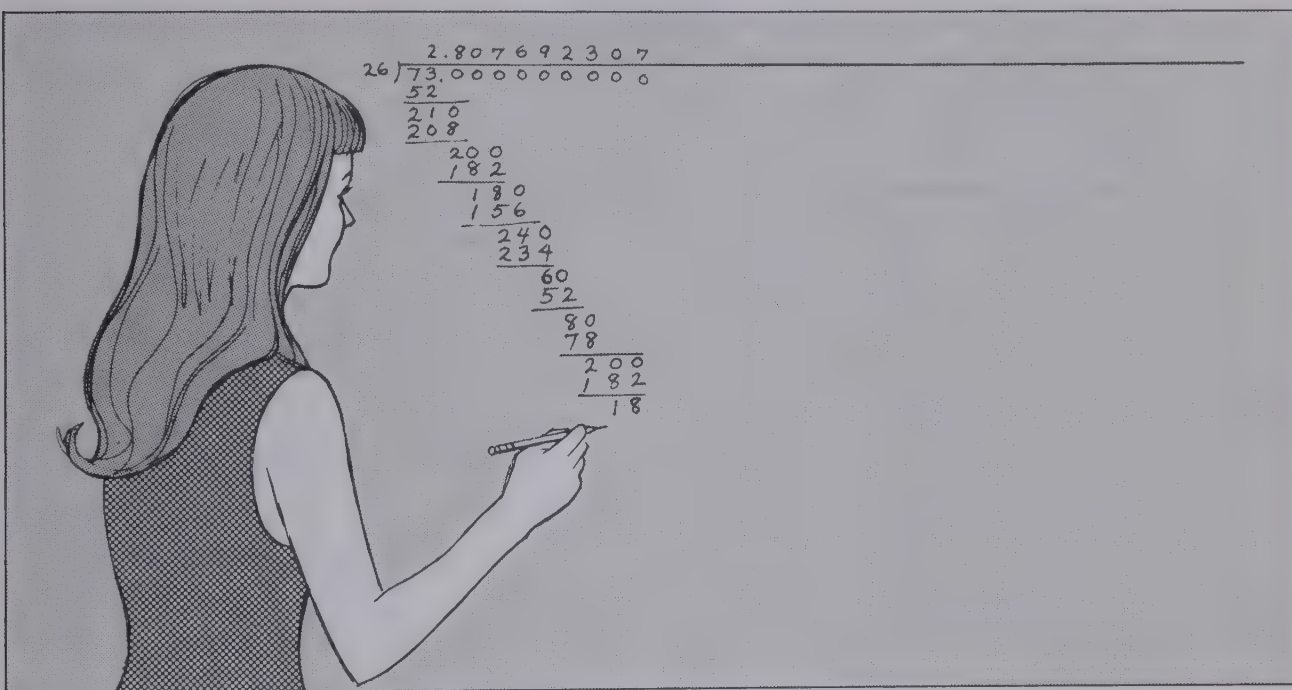
## TEACHING TIPS

**Responses to Expect**: Students will ask, "What is the gas?" Don't tell students directly but let them guess and experiment. Eventually, with hints if necessary, have someone ignite the gas. When they guess hydrogen, affirm this. The question will arise again in the next investigation.

Expect, "How do you divide?" or more frequently, "Which goes into which?" Write a division symbol on the board with the word "length" where the divisor goes and the words "gas volume" where the dividend goes.

**Practical Hints**: Have the class go through a practice run, using water instead of acid. Students need the manual practice of handling the equipment. Walk around to see if they can get the ribbon into the graduate without letting air in.

If time permits, you may want the procedure repeated. Results will be more uniform. Try having students roll up the ribbon into gelatin capsules. This gives them time to insert the ribbon in the graduate before gas production starts.




Give help with arithmetic and graphing. Watch out for students who can't stop dividing and must be told to round off.

Safety is a consideration whenever acids are handled. A harangue on safety will not solve anything, but quiet insistence on something like wearing safety goggles (required in several states as well as many school districts) will put the point across.

**Discussion and Review**: The discussion will be engendered by the straight line graph and similar hydrogen to magnesium ratios. Your line of questioning is based upon: What is there about matter that makes it behave this way? Particles that can stick together only one way should evolve as the easiest answer.

## ENRICHMENT

Some may want to read about the early chemists. Dalton and his era is appropriate. Conant's *Harvard Case Histories in Experimental Science* would be rough going for these students, but you might read from them for use in discussions.

A skillful student can verify this constant ratio of reactants for other materials by doing titrations with bases and acids. Let him find the ratios of volume of an acid to weight or volume of a base for different starting amounts of material.

## REFERENCES

### Multi-Media Aids

*Definite and Multiple Proportions:* 16 mm film, P.S.S.C.

*Combining Volumes: Synthesis of Water:* Film loop, color, 3 min., Ealing Cat. No. 84-0173/1.

## POSSIBLE ANSWERS

1. Students' predictions. (They will tend toward fitting particles together but don't penalize the holdouts.)
2. The ribbon fizzes when it touches the acid. The ribbon disappears and gas is left.
3. It is (almost) a straight line.
4. They are all about the same.
5. The ratios of gas to ribbon were all alike so the ratios of particles sticking together must be the same. (Allow for wide variation in how this is expressed.)
6. Flat. (Awful, it wouldn't rise, etc.)
7. It would fall apart. (It wouldn't last, etc.)
8. It knocks. (It has no pep, etc.) The mileage is low.
9. (Answers will vary: Things wouldn't work right, etc.)
10. (This depends upon the prediction: Probably *yes* if the student chose to fit particles together.)

**CONCEPT SUMMARY**: Substances react with each other in constant proportions.


Different groups should be assigned different numbers of cells for their electrolysis (from 3 to 6 cells).

**PURPOSE**: Show that the concept of constant proportions applies to decomposing materials as well as to combining them.

**DEVELOPMENT**: (A) Students will decompose water by electrolysis, and (B) will do splint tests on the hydrogen and oxygen produced.

(D) The constant proportion of the hydrogen and oxygen can be explained most easily by assuming that particles had been fitted together in some regular way.

**HIGHLIGHT**: All the teams collected the same *ratio* of hydrogen to oxygen even though the actual amounts were different (No. 21, page 66).

**WARNING**: IF YOU USE AN ACID ELECTROLYTE, KEEP A FRESH BAKING SODA SOLUTION HANDY TO NEUTRALIZE ACID SPILLED ON CLOTHING.

**MATERIALS** (for each team of two)

*Part A–Electrolysis of water*

Battery pack with 4 flashlight cells
Wires, clip leads–2 are needed
Electrodes (platinum, or stainless steel or carbon)–2 are needed
Beaker, 250 ml
Sodium carbonate solution, 200 ml
Tape, masking, 8" length
Paper towel
Test tube, 18 mm x 150 mm–2 are needed

*Part B–Testing oxygen and hydrogen*

Splints, wood–4 are needed

**Preparation of Materials**

In order to get voltages greater than that provided by 4 cells, have some pairs of teams hook up their battery packs in series. Each team can then draw off whatever voltage has been specified for it.

Most dry cells last only a year or two, even if they are not used; therefore, don't try to stock up.

The type of electrolyte will depend upon the electrodes used. With platinum electrodes use dilute (1M) sulfuric acid. This is prepared by adding 50 ml of concentrated acid to enough water to make one liter. With stainless steel electrodes, use sodium carbonate. This is prepared by dissolving about 200 g of solid sodium carbonate in enough water to make one liter.

The concentrations are not critical; more dilute solutions will cause slower reactions which require more time.

**TEACHING TIPS**

**Responses to Expect**: Students will ask, "What kind of gas is it?" Hold off replying until the latter part of the investigation when the tests are done. Expect questions about the electrolyte, such as, "What if you drank it?" Some of the boys have had experience with battery acid, so there is a peer group information source. *Strive for caution without undue fear.*

**Practical Hints**: Have a practice set-up session using water. The problem of getting electrodes in the test tubes without air bubbles can be solved more leisurely this way. Let the students switch to the electrolyte when they are more sure of themselves.

Set up a source of hydrogen and oxygen of your own. Teams using only a few cells, or who have problems, will not make enough gas to do the tests, so you can either supply them or demonstrate the tests yourself. You may want to repeat the tests during discussion. It's a good excuse to pop the hydrogen yourself.

Watch out for puddles of electrolyte left on working surfaces. Be a little more fussy than usual about cleaning up after the lab.

**Discussion and Review**: The primary target here is to make students realize that there is order in the way matter comes apart. The fact that different numbers of cells produced different amounts of gas is used to lend emphasis to the fact that the gas ratios still stay the same. Then the students are led to infer that the particle picture of matter explains this consistent behavior.

Identifying the gases is a secondary consideration. It has two uses though. First, the popping hydrogen and flaring splints create interest. Second, oxygen is introduced, an element which carries the brunt of the attack on the concept of elements in the next investigation.

## ENRICHMENT

For the readers, the works of Faraday in electrolysis are fundamental. The antiquity of his writings can be a problem. There are many books on his work written in a more modern vein. Other reading on electrolysis or electroplating would fit in here.

For the doers, attempting to electroplate something is a good activity. Some of the boys may be familiar with shops where they have auto parts chromed. Automobile supply houses have kits that permit minor chrome plating, using the car's storage battery. A careful lab worker can do some measurements in electroplating. He will find that the weight lost by one electrode equals that gained by the other.

Other substances can be broken down by electrolysis. Once again the constant proportions should appear. Avoid producing excessive amounts of poisonous gases like chlorine.

## REFERENCES

### Books and Articles

Faraday, Michael, *On the Various Forces of Nature.* New York: Thomas Y. Crowell Co., 1961. Pp. 119-135.

Wolff, Peter, ed. *Breakthroughs in Chemistry.* New York: New American Library, Inc., 1967.

### Multi-Media Aids

*Oxygen:* 16 mm, color or black and white, 11 min., Coronet Films Cat. No. 206.

*Electrochemical Reactions:* 16 mm, color or black and white, 13½ min., Coronet Films Cat. No. 1411.

*Definite Proportions: Electrolysis of Water:* Film loop, color, 3½ min., Ealing Cat. No. 84-0165/1.

**POSSIBLE ANSWERS**

1. (This is tough; many students will give up. Try indirectly to channel them to saying they can't explain without particles, if this is the case.)
2. The particles fit together in some special way.
3. (The students' predictions will vary, but the previous investigation will slant their predictions toward constant proportions.)
4. Bubbles rise from the electrodes.
5. Fewer bubbles rise from the electrodes.
6. The gas popped (or exploded).
7. Nothing; the splint went out.
8. Yes. The flaming splint caused an explosion.
9. It burned more brightly.
10. The splint burst into flame.
11. No. They have different properties.
12. Hydrogen, because hydrogen explodes. (Not all students will realize that hydrogen explodes, but the picture in the text of the Hindenburg exploding may suggest it to some.)
13. Oxygen, because oxygen makes things burn more brightly. (Not all students realize that oxygen will cause a glowing splint to reignite, so expect that some students will be unable to answer this.)
14. The battery may be giving off hydrogen.
15. Oxygen.
16. By passing electricity through liquid.
17. Oxygen.
18. By passing electricity through a liquid.
19. Twice the volume of gas at the negative electrode.
20. 2 to 1.
21. 2 to 1.
22. The longer the running time, the greater the amount of gas.
23. No; the number of batteries determines how fast the gases are given off.
24. Water came apart in constant proportions of 2:1.
25. (Answers will depend on predictions.)

**CONCEPT SUMMARY:** Matter comes apart in constant proportions.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 9 (1-1½ periods)

**PURPOSE**: Give depth to the concept that the universe beyond Earth is made up of the same particles that make up Earth.

**DEVELOPMENT**: Oxygen gas will be produced by two chemical reactions: (A) by heating mercuric oxide, and (B) by reacting sodium peroxide with dilute sulfuric acid.

(C) By finding the same substances evolved from different materials, students will learn that there is a simple set of basic types of matter of which all the rest are made.

**HIGHLIGHT**: The same gas, oxygen, shows up for the third time (No. 4, page 68).

**WARNING**: SODIUM PEROXIDE SHOULD BE DISCARDED BY FLUSHING DOWN THE DRAIN. IT WILL IGNITE IF DROPPED IN WASTE BASKETS.

**MATERIALS** (for each team of two)

*Part A–Decomposing mercuric oxide*
Mercuric oxide, technical, about ½ ml
Burner, Bunsen
Test tube, Pyrex, 18mm x 150mm
Test tube clamp (or burette clamp)
Splints, wood–about 3 are needed

*Part B–Reacting sodium peroxide with dilute sulfuric acid*
Sulfuric acid, dilute, about 6 ml
Test tube, Pyrex, 18mm x 150mm
Sodium peroxide, about ½ ml
Splints, wood–about 3 are needed

**Preparation of Materials**

Have the bottle of mercuric oxide on a sheet of paper or paper towels so that spills may be picked up easily. To avoid crowding, put the sodium peroxide at a different place. Each reagent should have a spatula or scoop put with it. Dilute sulfuric acid is prepared by adding 168 ml of concentrated acid to enough water to make one liter. If unsure, err on the side of a more dilute solution.

**TEACHING TIPS**

**Responses to Expect**: Expect a spate of questions about the materials: what are they, how dangerous, etc. Work for reasonable caution but not panic. Students should know enough to keep things out of their mouths.

When they have identified mercury, the business of coating pennies will come up. For the record: copper dissolves in the mercury to form a copper-mercury alloy (commonly called an amalgam). Inform students that mercury is toxic when either absorbed through the skin, ingested, or its vapor inhaled.

**Practical Hints**: Collect the test tubes after heating mercuric oxide in part A. It will save future problems from developing.

It takes vigorous heating of the mercuric oxide to get enough oxygen to ignite the splint.

The addition of a generous spatula full of sodium peroxide is necessary to evolve enough oxygen to light the splint.

Mask the labels of the chemical containers; otherwise some students will pick up the names and get ahead of the game.

Keep baking soda handy in case of acid spills.

**Discussion and Review:** The train of reasoning first uses the property of igniting the glowing splint to establish that the gas is oxygen. Questions 5 and 10 show that this is but one of several substances making up the kinds of matter being used. Then the ubiquitousness of oxygen is used to establish it as an elemental substance in the chemical scheme of things.

## ENRICHMENT

Those who like to read can look up the discovery of the different elements. Some students may want to know how the elements were named. This is more interesting if they can see a periodic chart with symbols; they will probably be curious about why iron is Fe.

Let more active students obtain iron or lead from their oxides, using charcoal blocks, burners, and blowpipes. They could test the iron oxide in advance with a magnet and then find that magnetic properties have appeared in the final product.

## REFERENCES

### Books and Articles

Asimov, Isaac, *Building Blocks of the Universe.* New York: Abelard-Schumann, Ltd., 1961.

Asimov, Isaac, *Search for the Elements.* New York: Basic Books, 1962.

Ley, Willy, *Discovery of the Elements.* New York: Dell Publishing Co., 1968.

Newton, Vernon. *Adam's Atoms.* New York: Viking Press, 1965.

### Multi-Media Aids

*Fire and Oxidation:* 16 mm, color or black and white, 11 min., Coronet Films Cat. No. 1518.

*The Elements: Building Blocks:* 16 mm film, N. E. T.

*The Elements: from Alchemy to Chemistry:* 16 mm film, 29 min., N.E.T.

## POSSIBLE ANSWERS

1. Silvery droplets.
2. Mercury.
3. The splint burst into flames.
4. Oxygen.
5. More than one. Two things, a gas and a liquid were produced.
6. It fizzes.
7. The splint burst into flames.
8. Yes. It has the same property.
9. Yes. The liquid is cloudy.
10. More than one. After the gas came out, something was left.
11. Yes. It had the same properties each time.
12. (a) True.
    (b) True.
13. Elements.
14. Atoms.
15. Students' predictions. (Either there are or there aren't tinier particles.)

**CONCEPT SUMMARY**: All matter is made of combinations of the same basic substances, the elements.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 10 (2-3 periods)

**PURPOSE**: Develop the notion that there are smaller particles inside atoms.

**DEVELOPMENT**: (A) Students will charge plastic strips and observe electrostatic attraction and repulsion. (B) They will observe the way an electroscope works, and will see how (C) the Geiger tube and (D) cloud chamber detect radioactive material. (E) They will examine a radioactive substance's decay curve.

The fact that something is ejected from within the atom is seen as evidence that the atom is constructed of smaller pieces.

**HIGHLIGHT**: The match flame makes the electroscope discharge (No. 19, page 73).

**MATERIALS** (for each team of two)

*Part A–Electrostatics*
Strip, vinyl plastic, 12" x 1" x 1/16"–2 are needed
Strip, acetate plastic, 12" x 1" x 1/16"–2 are needed
Cloth, cotton, piece 5" square
Cloth, wool, piece 5" square
Tape, masking, about 20" long

*Part B–Electroscope*
Test tube, 18mm x 150mm
Cloth, silk, piece 5" square
Electroscope, "coffee can" or other type
Matches, 2 or 3
(Strip, vinyl or acetate used in part A)

**MATERIALS** (for the teacher)

*Part C–Geiger tube detection*
Geiger tube
Audio-amplifier or other device for displaying the Geiger tube's response and loudspeaker
Power supply, high voltage, to power the Geiger tube
Radioactive sample, in sealed plastic, 50 microcurie Beta emitter

*Part D–Cloud chamber*
Cloud chamber with radioactive source
Eyedropper
Dry Ice, ½" thick to set chamber on
Flashlight

**Preparation of Materials**

Part B: electrostatic equipment is often temperamental. To increase the chances of good performance, wipe the test tube with alcohol or some other solvent and a clean rag. Use clean cotton and wool squares. If necessary, wash them or replace them at intervals. Sometimes an obstinate test tube will take a charge after it has been cleansed by passage through a flame.

Part C: if you do not have radiation detection equipment and are not able to buy it, you can probably borrow it from the physics teacher of a local high school or from local Civil Defense personnel. The physics teacher may be willing to send you a student demonstrator. If neither of these sources can help, then part C may be omitted without serious loss in continuity.

## TEACHING TIPS

**Responses to Expect:** How dangerous is the radioactive sample? It isn't, as long as it remains sealed and is not ingested.

For simple questions about charge and electroscopes, the answer is "Try it."

The table of remaining material is not quite accurate for a radioactive isotope of phosphorus. Its half life is 14.3 days. It is not a naturally occurring isotope.

**Practical Hints:** When the students have to charge the electroscope they will have trouble by just rubbing the knob or plate with a charged plastic strip. To overcome this difficulty, they can charge it by induction: Bring the charged strip or test tube very close to the electroscope, then *briefly* touch the knob or plate of the scope with your finger. Remove the charged rod, and the leaves or the straw will take the charged position. At this level, the best explanation for the students is that the charged rod either pushes charge on your finger or pulls it off, leaving some charge trapped on the electroscope. A discussion of this process appeared in *The Physics Teacher* several years ago. It is somewhat difficult for a class discussion.

**Discussion and Review:** The important point is that something comes out of atoms. It comes out of recombining atoms in flames. It comes out of atoms that are changing from one element to another. The electroscopes, Geiger tube, and cloud chamber are incidental, they just show that these particles are present.


## ENRICHMENT

For the readers, the story of Becquerel and the Curies makes a fine starting point.

By observing movement when rubbed and held near one of the charged plastic strips, students may want to categorize some common materials as "like vinyl" or "like acetate." They can try plastic rulers, combs, etc.

For the active students, building and operating cloud chambers is always fascinating. The peanut butter jar variety or the very simple inexpensive types in most science supply catalogues are starting points. Elaboration is only limited by the student.

Have a student or committee contact local Civil Defense people for a demonstration of radioactivity.

## REFERENCES

### Books and Articles

Gamow, George, and John M. Cleveland, *Physics: Foundations and Frontiers.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1960. Pp. 415-422.

Williams, John E., H. Clark Metcalfe, Frederick E. Trinklein, and Ralph W. Lefler, *Modern Physics.* New York: Holt, Rinehart, & Winston, 1968. Pp. 239-244.

### Multi-Media Aids

*Atomic Radiation:* 16 mm, black and white, 13 min., EBF Film No. 655.

*Electrostatics:* (2nd ed.) 16 mm, black and white, 11 min., EBF Film No. 464.

*Man Discovers the Atom:* Filmstrip, EBF No. 8860.

*Radioactivity:* 8 mm film loop, color, 3-1/3 min., Ealing Cat. No. 80-3346/1.

*Introduction to Electrostatics:* 8 mm film loop, color, 3½ min., Ealing Cat. No. 80-2819/1.

*Radioactive Decay:* 8 mm film loop, color, 5 min., Ealing Cat. No. 80-2009/1.

## POSSIBLE ANSWERS

1. Hanging piece swings away (they repel).
2. The same.
3. Hanging piece swings away (they repel).
4. The same.
5. Swing away from each other (repel).
6. Swing apart (repel).
7. Swing together (attract).
8. They swing together.
9. Opposite.
10. Repel.
11. Attract.
12. Yes. (Some students may say *no;* remember, they have no experimental basis for an answer to this question.)
13. Yes. (Some may say *no.*)
14. (Some students will say that the smallest thing that can hold a charge is an atom; this question is designed to get them thinking about size.)
15. The leaves of the scope move apart (diverge).
16. No; the leaves stay apart.
17. The leaves move together (it discharges).
18. The leaves move together (it discharges).
19. Pieces may be passing between flame and electroscope.
20. A clicking sound every few seconds.
21. Lots of clicking sounds.
22. You hear less clicking.
23. (Answer depends on the Geiger tube model.)
24. The noise gets weaker away from the sample.
25. The noise gets louder.
26. (Depending upon the equipment, you get more clicks, flashes, numbers, etc.)
27. More drops of paint at 1 foot.
28. The clicks are caused by particles being shot out of the sample.
29. A streak of whitish fog goes shooting across the chamber.
30. The whitish streaks stop.
31. There are whitish streaks again.

32. The sample.

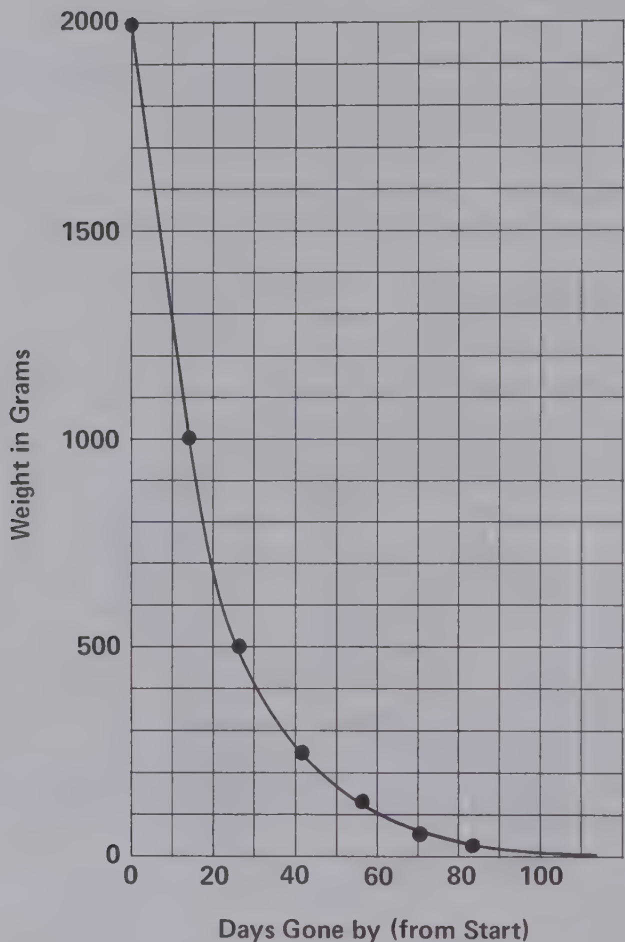
33. Small particles.

34. It seems likely the clicking sound was caused by tiny particles. (Students will have some difficulty answering this question because the experimental evidence they have been presented with is still rather tenuous.)

35. Has the shape of a quarter-moon, starting almost vertical on the left and sloping down on the right.

GRAPH NO. 1

REMAINING RADIOACTIVE MATERIAL




36. Find the time you want on the bottom. Go up until you come to the curve. Go sideways to the left edge. Read the number of grams.

37. The curve shows some radioactivity will last a long time. *Or* it never goes to zero. *Or* there's always a tiny bit left. Etc.

38. Find one-half the amount on the left edge. Go straight across to the curve. Go straight down and see what the time is.

39. How much of the radioactive material there was to start with, and the amount of it which is small enough to be harmless.

40. Medical treatment; radioactivity is used to retard or stop cancer growth. (Some students may be aware of other effects that are not bad.)

**CONCEPT SUMMARY**: Atoms are made of charged particles.

## PHYSICAL SCIENCE IDEA 2: MATTER, Investigation 11 (1½-2 periods)

**PURPOSE**: Give depth to the concept that the universe beyond Earth is made up of the same particles that make up Earth.

**DEVELOPMENT**: (A) Students will repeatedly roll a marble down a ramp into a cluster of differently colored marbles. (B) They will find that the color array of marbles knocked out of the cluster tells something about the color array in the original cluster.

(C) An appreciation of the effect of averaging many events to see a trend is developed and used to validate the particle picture of the atom.

**HIGHLIGHT**: The averages of the colors knocked out are similar to the colors in the loop (No. 4, page 79).

**MATERIALS** (for each team of two)

*Part A–Marble bombardment*
Marbles, of one solid color–15 are needed
Marbles, of a second solid color–15 are needed
Marble, of a third color–1 needed
Ruler, 12" metric
String, 20" length
Chalk, small piece
Meter sticks, or strips of lath to keep marbles on the desk–3 are needed

**TEACHING TIPS**

**Responses to Expect**: Sophisticated students will have heard that there are other particles than the proton, the electron, and the neutron. Point out that these particles only appear during violent interactions of other particles. Further point out that the picture of matter is not yet complete; there is more to learn; science has no final answers, etc.

Be prepared to give very simple ideas about how particles are accelerated. Point out that electrical and magnetic interactions with charged particles are the bases of the various accelerators or "atom smashers."

**Practical Hints**: Watch that the two colors are evenly distributed within the cluster of marbles. If colors are segregated there will be a bias that gives averages that vary widely from the ratios in the cluster.

See that the students return all of the marbles to the cluster for each trial.

Have students round off their averages to the nearest whole marble. It will reduce arithmetic and make comparisons simpler. Expect to help with the division.

**Discussion and Review**: The first task is to reach agreement that the method of bombardment is a reasonable way to explore the "nucleus." From there, the picture of the atom is developed. Students can usually see that particles must be moving or the opposite charges would unite, but solar system atoms are not fashionable.

By now, data from moon probes is sufficient to bolster the idea embodied in question 6 that matter is much the same throughout the universe. Don't lecture, but ask if people always believed this. (They didn't, the Ptolemaic Universe had earthly and celestial matter.)

**ENRICHMENT**

The readers have several areas to explore. One of course is the subject of accelerators. Other areas are Rutherford and the nucleus, Chadwick and the neutron, Lawrence and the cyclotron. A student interested in social aspects should be turned loose on the international cooperation necessary for the European project CERN.

Some students may want to argue the validity of spending hundreds of millions on accelerators when internal problems go begging.

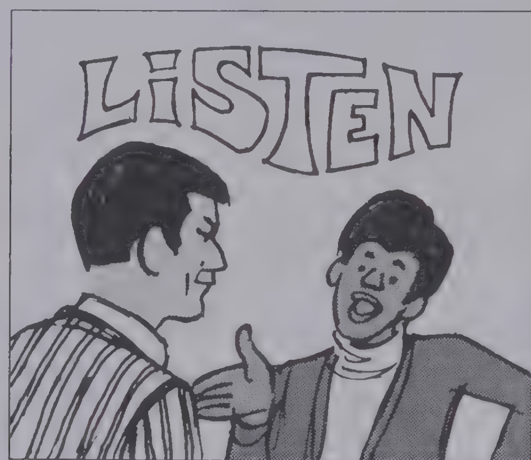
## REFERENCES

### Books and Articles

Asimov, Isaac. *Inside the Atom,* rev. ed. New York: Abelard-Schumann, Ltd.
Boorse, Henry A., and Lloyd Motz, *The World of the Atom* (2 vol.) New York: Basic Books, 1966.
Kogan, Philip. *The Cosmic Power: Foundations of Nuclear Physics.* Boston: Ginn & Co., 1966.

### Multi-Media Aids

*Exploring the Atomic Nucleus:* 16 mm, color or black and white, 13½ min., Coronet Cat. No. 1711.
*Synchrotron:* 16 mm, color, 14½ min., AEC.
*A is for Atom* (rev. ed.): 16 mm, color, 15 min., AEC or General Electric Co.
*Atom Smashers* (rev. ed.): 16 mm, 18 min., AEC.
*Strange Case of the Cosmic Rays:* 16 mm, color, 60 min., Bell Telephone Co.




## POSSIBLE ANSWERS

1. A food store.
2. To keep the conditions consistent.
3. They are about the same.
4. Yes. The average of many trials will show a ratio of parts similar to what is inside.
5. Positive.
6. Matter throughout the universe is made of the same particles.

**CONCEPT SUMMARY**: The whole universe is made of the same particles as those found on Earth.

**IDEA SUMMARY**: The universe is composed of matter and all matter is made of tiny particles.

# Idea 3
## Energy

Idea 3 of IIS uses nine investigations to make its point, that:

WHEN PARTICLES OF MATTER INTERACT, ENERGY MAY BE EITHER RELEASED OR ABSORBED.

Once again remember that there is no one "sacred" way of stating the Idea. We are looking for understanding, not memorization of facts or slogans. The Ideas and concepts may come up in a different form every time.

The sequence opens by defining work. The second investigation discloses the different ways work may be done. The following two investigations explore some of the simple machines, and as a corollary to the permanence of matter found in the previous Idea, they establish the indestructibility of energy. Investigation 5 investigates fuels as a source of energy, while the next investigation concerns itself with some endothermic and exothermic interactions. Investigations 7 and 8 go into nuclear energy, while the last investigation looks into the equivalence of matter and energy.

Here again advanced familiarity with the Idea is important. The sequence of preparation is critical for Investigation 7, where sufficient time is needed for the radioactive samples to expose the film.

# PHYSICAL SCIENCE: IDEA THREE (ENERGY)

## When Particles of Matter Interact, Energy May Be Either Released or Absorbed

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. I COULD WATCH IT BY THE HOUR | Work is force acting over a distance. | Rolling a spool with a rubber band; getting heat from bending a paper clip |
| 2. IT'S ALWAYS WORK | Work takes many forms, such as light, heat, and electricity. | Radiometer; electromagnet |
| 3. THERE MUST BE AN EASIER WAY | Work is made easier with simple machines. | Measurements based on pulley; lever |
| 4. IS THIS ON THE LEVEL? | Simple machines make work easier by using less force over a longer distance. | Measurements on an inclined plane |
| 5. HEAT MAKES WORK AND WORK MAKES HEAT AND– | Burning fuel does work through the expansion of heated gases. | Motion of test tubes and pin wheels produced by expanding gases |
| 6. STOP FUELIN' AROUND | Fuels release energy by reacting with other matter. | Paper burned in closed container; temperature changes from dissolving chemicals |
| 7. GO MAD WITH POWER | Energy comes from reacting nuclei of atoms. | Exposure of film by radiation and heat; solar cell; a simulated chain reaction with wooden blocks |
| 8. DON'T LET IT RUB OFF ON YOU | Radiation safety depends on shielding, space, and money. | Geiger counter readings with changes in distance and in shielding |
| 9. BUT YOU CAN'T GET SOMETHING FOR NOTHING! | Energy may be either released or absorbed when particles of matter interact. | The conversion of matter to energy demonstrated through use of simple arithmetic |

## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 1 (1-1½ periods)

**PURPOSE**: Introduce the concept of work as force acting over a distance.

**DEVELOPMENT**: As examples of work being done, (A) weights will be moved and (B) a rubber band will propel a toy.

Students will understand the scientific meaning of work. It will become a more tangible idea for later use.

**HIGHLIGHT**: The ability to do work is stored in the rubber band (No. 13, page 84).

**MATERIALS** (for each team of two)

*Part A–Lifting a weight*
Weight (a brick, book, or other object)

*Part B–A rubber band worker*
Spool, wooden, thread
Candle, slice of, wick removed, 3/4" diameter x 1/4"
Match sticks, 2 required
Rubber band
Tape, masking, ½" length

*Part C–Heat from work*
Paper clips, one per student

**TEACHING TIPS**

**Responses to Expect**: Some students will not accept at first the idea that they are not performing work when they are straining against an immovable object. They will have to distinguish between effort and accomplishment, or in simple terms, the difference between physical and physiological activity.

**Practical Hints**: Don't give Idea 3 away with an overview of the whole unit. Open with the reading of the introductory paragraphs of Investigation 3 as though it were just another investigation.

Demonstrate assembling the "spoolmobile." See diagram in the text. A paper-clip hook may be used to pull through the rubber band if it is too short. Don't actually operate it yourself until the students have worked theirs.

For variety, if the edges of the spool are notched, they will climb minor obstacles that a smooth rim slides off.

The paper clip bending activity sometimes finds students who won't put that dirty thing near their mouths. Walk about dispensing fresh ones with a pair of forceps. It would also be advisable to circulate a wastebasket to collect them.

After the paper-clip activity, expand the work-heat idea by sawing a piece of wood in half. Have some students, particularly girls, touch the blade.

**Discussion and Review**: Heat is not as important as the idea of combining force and motion to produce work. This is the main theme. Use commonplace examples, the force on the comb, and the distance through the hair, etc.

**ENRICHMENT**

Have a more mathematical student demonstrate that lifting two pounds one foot is as much work as lifting one pound two feet.

Have a student report on the forces needed to lift a rocket off the launch pad.

Have some students debate whether a number of commonplace activities are or are not work.

Have one or more students build spoolmobiles of their own design. Race them. (No gambling, please!)

## REFERENCES

### Books

Brinkerhoff, R., B. Cross, F. Watson, and P. F. Richardson, *The Physical World* 2nd ed. New York: Harcourt, Brace & World, 1963. Page 137.

Pella, Milton D., *Physical Science for Progress.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970. Pp. 59-60, 88-90.

### Multi-Media Aids

*Force + Distance = Work:* Overhead transparency, School Products Cat. No. Sc-8264.

*Laws of Motion:* 16 mm film, color, 13 min., E. B. F. Film No. 756.

*Transferring Force:* Overhead transparency, School Products Cat. No. Sc-8272.

## POSSIBLE ANSWERS

1. Something pulls them. (*Or* pushes them, gives them a shove, etc.)
2. I pushed it. (*Or* pulled it.)
3. Force.
4. Force (a pull).
5. Work.
6. Yes. The car moves so force acted over a distance.
7. No. Nothing moved. (No distance was covered.) (The distance is zero.)
8. Students' answers. (Probably *yes.*)
9. Yes. The stick is being pushed over a distance. (*Or* forced over a distance.)
10. It moves over the table.
11. Force is acting over a distance.
12. From the rubber band (the wound up rubber band).
13. It was stored. (Some students will probably say that the work disappeared for a while. This answer is not unreasonable; it suggests that the work was temporarily in a dormant or stored state.)
14. Students' predictions. (These will vary, some may have heard of friction and heat previously and use the information.)
15. The part that bent is warmer.
16. Yes. Force acted over a distance to straighten the wire.
17. Hot (*or* warm).
18. Hot (*or* warm).
19. It turns to heat.

## CONCEPT SUMMARY:

A. Work is acting over a distance.
B. It takes work to make things move.

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## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 2 (1-1½ periods)

**PURPOSE**: Show that light, heat, and electricity can all do work.

**DEVELOPMENT**: Using a radiometer and an electromagnet, students will see that (A) light, (B) heat, and (C) electricity all produce motion; that they all cause a force to act over a distance.

Students will see that energy continuously takes a number of forms as it does the work of running the universe.

**HIGHLIGHTS**: Light and heat cause the radiometer to spin (No. 4, p. 88 and No. 7, p. 89).

Electricity causes the tacks to move (No. 13, p. 90).

**MATERIALS** (for each team of two)

*Parts A & B–Radiometer*
Paper towels–2 are needed
Supply of hot water, 100 ml

*Part C–Electromagnet*
Spike, iron, 6" long, ¼" diameter
Wire, enameled, B & S 24, 20 feet
Battery pack, 4 flashlight D cells
Small bits of iron such as carpet tacks, screws, nuts, paper clips, etc.
Sandpaper, fine grit, 3" square
Clip leads–2 are needed

**MATERIALS** (for the class)

*Parts A & B–Radiometer*
Radiometer–4 are needed per class (more if available)

**TEACHING TIPS**

**Responses to Expect**: The radiometer is a toy. What kind of work does light really do? The term "energy" won't be introduced for several investigations, but you can bring out the fact that plants do work in growing and that this work ability is transferred to people when they eat. Much of this is in the biological realm, which students may or may not have had, but most will have been exposed to TV commercials about energy from food.

**Practical Hints**: If sunlight is not entering your classroom, try setting up a mirror outside that will send a beam in through a window or door. Use your movie or slide projector as an alternate source.

It is not necessary that each class make electromagnets. Let succeeding classes use the electromagnets of the first class. A strip of masking tape will hold the coil in place on the nail from class to class. If the nail appears to retain some magnetism, reverse the connections and make momentary contact with the battery. This will usually demagnetize it.

Care should be taken in constructing the electromagnet, as it will be used during three later investigations (Idea 5, Investigations 5, 6, and 8).

If there are no battery holders or other methods available, the students can hold the bare wires on the ends of the flashlight cell.

Some students may want to know how the radiometer works. A frequent explanation is given that the dark sides of the vanes become warm first and the air adjacent to them is heated and expands. This is not an accurate statement; the facts are more obscure and probably too abstruse for these students. See *The Physics Teacher*. **6**:358-363, No. 7, October, 1968.

**Discussion and Review:** What is wanted is reiteration of the many ways in which work is done. Students may not have thought of lights or toasters as doing work even though they will ask if a device is working. Here the common idiom is more accurate than they have realized.

The discussion may be extended to other ways work is done; i.e., sending television or radio waves. But develop this theme only as long as the response is spontaneous and not forced.

## ENRICHMENT

Have a more studious student report on Joule's work on the conversion factor between heat and work. There is a story about him taking the temperature above and below a waterfall while on his honeymoon; students usually find this amusing.

Some students may want to demonstrate work done by other means, such as growing plants lifting weights, simple water wheels, or whatever they may devise.

## REFERENCES

### Books

Halacy Jr., D. S., *The Coming Age of Solar Energy*. New York: Harper & Row, 1963.
Rau, Hans, *Solar Energy*. New York: The Macmillan Co., 1964.

### Multi-Media Aids

*Energy from the Sun:* 16 mm film, 16½ min., McGraw-Hill Cat. No. 653207 (B/W), 653307 (color).
*Waves and Energy:* 16 mm film, 11 min., E. B. F. Cat. No. 1875 (B/W), 1874 (color).

## POSSIBLE ANSWERS

1. Heat.
2. Work could produce heat.
3. Students' predictions, such as "there is a close relationship between heat, light, and work; when there is one present, there is frequently the other; etc."
4. It turns (spins).
5. It stops.
6. It takes work to move the fins. They stop when the light is cut off.
7. It turns.
8. It stops.
9. The fins stop when the heat is gone.
10. Heat and light are related.
11. Electricity.
12. Nothing.
13. The bits of iron (tacks, screws, etc.) move toward the nail and stick to it.
14. Yes. The iron moved.
15. It gets hot.
16. They are related. They all do work. They turn into each other; light into heat, etc.
17. (It depends on the students' predictions. They will usually answer *yes.*)

**CONCEPT SUMMARY:** Work takes many forms, such as heat, light, and electricity.

## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 3 (1½-2 periods)

**PURPOSE**: Introduce the simple machine as a device to make work easier.

**DEVELOPMENT**: Students will measure the force required to lift a weight with (A) pulley and (B) lever.

They will see that machines let the operator apply less effort, and that since this smaller effort must be applied over a greater distance, the machine doesn't provide something for nothing.

**HIGHLIGHTS**: The ratio of forces is about the same as the ratio of distances (No. 10, page 94).

The farther the spring balance gets from the balancing point the lower it reads (No. 22, page 95).

**MATERIALS** (for each team of two)

*Part A–The pulley*
Pulley, single
Support for pulley (ring stand and burette clamp, etc.)
String, 5 foot length
Balance, spring, 250 g capacity
Weight, 8 oz.
Meter stick

*Part B–The lever*
(Balance, weight, and meter stick of part A)
Paper clip, 2" length
Tape, masking, 8" length

**Preparation of Materials**

If you have C-clamps but no ring stands, use a C-clamp to support the pulley. Clamp it to the edge of the desk so that the turning handle projects over the edge. Students can hang the pulley from the handle.

**TEACHING TIPS**

**Responses to Expect**: The students won't be excited about pulleys. Outside of an occasional flagpole, some may never have seen one. Spring balances intrigue students, and they will want to play with them.

**Practical Hints**: Go through the pulley setup slowly. You will have to help with knot tying. Some students have trouble getting the pulley right side up.

Help with the distance measurements. Synchronizing the 20 cm movement of the spring balance with measuring the load distance is a problem for students who are not used to handling things with precision.

Watch that the balances are used right-side up. If they are used upside down the readings will be too high.

Wait until part A is finished before going over the setup in part B. It is too complex to be remembered along with how to string a pulley.

**Discussion and Review**: The discussion should dwell on two ideas: (1) Machines make work easier, but (2) the same amount of work is done (it's just spread out over a greater distance).

In making the point that the work remains the same, it is probably better with most classes not to go into the mathematics of work as force times distance. The logic of less force and greater distance is sufficient. Many students would not see a strictly mathematical relationship, but don't cut off a student who does see it. He needs encouragement.

## ENRICHMENT

Have a student connect several pulleys to see how much he can cut down the force needed to lift the weight.

Have a student demonstrate the different kinds of levers.

Have a student bring in a bumper jack and compare the distance the handle moves up and down to how far the car rises per notch.

If a student is active in car racing, he may have access to the one-piece bar used to lift a wheel for quick tire changes during pit stops.

## REFERENCES

### Books

Brinkerhoff, R., B. Cross, F. Watson, and P. F. Richardson, *The Physical World,* 2nd ed. New York: Harcourt, Brace & World, 1963. Pp. 140-142.

Schneider, Herman and Nina, *Now Try This to Move a Heavy Load.* New York: William R. Scott, Inc., 1947.

### Multi-Media Aids

*Pulleys and Work:* 16 mm film, color, 14¼ min., Film Associates Cat. No. 16-262.

*Simple Machines: Levers:* 16 mm film, color or black and white, 5½ min., Coronet Films Cat. No. 751.

*Simple Machines: Pulleys:* 16 mm film, color, 5½ min., Coronet Films Cat. No. 752.

*Simple Machines:* 8 mm film cartridge film loop series, silent, color, E.B.F.

*Action of the Lever I:* 3 min., Cat. No. 80824.

*Action of the Lever II:* 3 min., Cat. No. 80825.

*Action of the Lever III:* 3 min., Cat. No. 80826.

*The Pulley I:* 3 min., Cat. No. 80828.

*The Pulley II:* 3 min., Cat. No. 80829.

*The Gear:* 4 min., Cat. No. 80831.

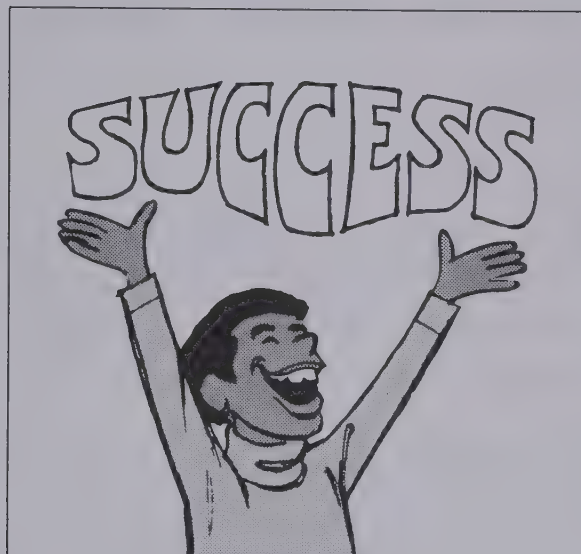
*The Wheel and Axle:* 4 min., Cat. No. 80833.

## POSSIBLE ANSWERS

1. Machines.
2. (There will be a spread of answers here from less work to easier work plus some without opinions. A good answer might be: Machines make the worker easier. The user of a simple machine uses less effort, but usually takes longer to do the job because the effort must be applied over a greater distance.)
3. (Student measurement.)
4. (Student measurement.)
5. (Difference between answers 3 and 4.)
6. (Student measurement.)
7. 2.
8. 10 cm.
9. 2.
10. The same.
11. On the moon, etc.
12. A lever.
13. (Student measurements.)
14. (Student calculation.)
15. They are the same.
16. (Student measurement and calculation.)
17. About ½.
18. Load distance to effort distance is 1 to 2, or 1/2.

19. 1/3 as much as the load.
20. (Students' data: should be about 1/3 of the load.)
21. 1/3.
22. Less.
23. More.
24. Lever.
25. It lets you use a smaller effort to lift a load.
26. Distance (usually more time, too).
27. Nutcracker, pliers, screwdriver used for prying, etc.

**CONCEPT SUMMARY**: Simple machines make work easier.



## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 4 (1-1½ periods)

**PURPOSE**: Continue to develop the concept of the simple machine: work is made easier by applying less force over a greater distance.

**DEVELOPMENT**: (A) Students will use first a 40 cm and then a 60 cm inclined plane to pull a cart to the same vertical height, and will find that the longer incline requires less of a pull.

(B) Questions are raised about the tendency toward automation in the operation of machines, and about the effect of this tendency on demands for skilled and unskilled labor.

**HIGHLIGHT**: It takes much less force than the weight of the car to move it up the incline (No. 3, page 97).

**MATERIALS** (for each team of two)

*Part A–Inclined Plane*
Cart, car, or truck, weighing 1 pound or less, preferably with negligible friction
Balance, platform
Wood, 60 cm x 10 cm x 2 cm
Balance, spring, 250 g capacity
Meter stick

**TEACHING TIPS**

**Responses to Expect**: Students will probably be more interested in playing with the cart at first. Let them establish that it is too heavy to weigh with the spring balance, if this is the case.

**Practical Hints**: Watch that the cars don't go off the tables and onto the floor.

If you are short on platform balances, have some groups do their force measurements while others are weighing the car.

Let the students run the cars up and down the incline while trying to take readings. They may decide to average the up and down variations rather than use a static reading.

To illustrate the screw, start by holding a sheet of paper cut in triangular shape, about 15°, 75°, and 90°. State that it is an inclined plane. Ask if the length or the height changes as you bend it into a "U" shape. Proceed to wind it into a spiral until the class recognizes the threads of a screw.

**Discussion and Review**: The use of the inclined plane as one of many force-saving devices is the important point. Stress the fact that both planes raise the load to the same height but it is easier to drag the car up the longer distance.

The data in part B can be tied to the general publicity that automation is receiving. Discuss it as long as response is active and not forced. The kids have heard the sermon before.

Table 2, Distribution of Unemployment by Education, while not specifically used to answer any of the questions, is relevant to the topic of part B and may provide information useful in a discussion.

**ENRICHMENT**

1. Have a student demonstrate the wedge as a variation of the inclined plane.

2. The standard jack that comes with the Toyota uses a screw coupled to a scissors type lever. Its mechanical advantage is so high the car may be jacked up with two fingers. Have a student demonstrate one–on a car if possible.

3. Borrow a house jack from an equipment rental business. Have one or more students measure the circumference of the circle the handle makes, and note how much the jack rises for one turn.

**REFERENCES**

**Book**

Sharp, Elizabeth N., *Simple Machines and How They Work.* New York: Random House, 1959.

**Multi-Media Aids**

*Simple Machines:* 16 mm film, black and white, 11 min., EBF Film No. 251.

*Simple Machines: Work and Mechanical Advantage:* 16 mm film, color, 13½ min., Coronet Films Cat. No. 1490.

*Simple Machines:* 8 mm cartridge film loop, silent, color E.B.F.

*The Inclined Plane:* 4 min., Cat. No. 80830.

*The Screw:* 3 min., Cat. No. 80830.

*The Wedge:* 3 min., Cat. No. 80832.

*Simple Machines Make Work Easier:* Filmstrip, color, 40 frames, Popular Science Publishing Cat. No. 554.

**POSSIBLE ANSWERS**

1. Students' data.
2. Students' data. (1/2 of the car's weight.)
3. 2.
4. 2.
5. The same.
6. Less steep.
7. Students' predictions. (Smaller force.)
8. Student's prediction. (A fast student will give an answer which is 1/3 of the car's weight.)
9. Student's data. (1/3 of the car's weight.)
10. Students' answers. (It should tend toward zero.)
11. The force acts over a longer distance.
12. Yes.
13. Yes.
14. Car ramps, wheel chair ramps, roadways that go over mountains, planks used to unload trucks, etc.
15. Fewer people are needed to run machines; more machines run automatically.
16. It became smaller.
17. It went way up.
18. The skilled workers.
19. The skilled workers.
20. They let you use less force.
21. Simple machines make work easier but they don't cut down the amount.

**CONCEPT SUMMARY**: Simple machines make work easier by using less force over a longer distance.

## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 5 (1½-2 periods)

**PURPOSE**: Show how gases, heated by burning fuel, expand and do work.

**DEVELOPMENT**: The student will see heated gases (A) lift a test tube and (B & C) turn a pinwheel.

(D) Attention will be turned from the success of fuel engines in satisfying man's needs to the problems they create in contributing to modern air pollution.

**HIGHLIGHTS**: The test tube rises as heat is applied (No. 4, page 102).

The pinwheel spins when placed over the burner and in the steam jet (No. 11, page 103).

**LOOK AHEAD**: Investigation 6, for each team you will need about 500 ml of tap water at room temperature. Read Investigation 7. A 50 microcurie beta emitter, radioactive sample, should be placed against the film 24 hours or more before the rest of the investigation is to be performed.

**MATERIALS** (for each team of two)

*Part A–Test tube piston*
Test tube, Pyrex, 18 mm x 150 mm
Culture tube, Pyrex, 13 mm x 100 mm
Clamp, test tube, or burette
Burner
Boiling chips, 2 or 3
Ruler, 12" metric

*Part B–Pinwheel No. 1*
Compasses, geometry
Scissors
Stick (ice cream, tongue depressor, or wooden splint, to make pinwheel handle)
Sheet of paper, about 5" x 5"
Ruler, 12" metric
Pin, common

*Part C–Pinwheel No. 2*
Cardboard strip, about 12" x ½" cut from a manila folder–2 or 3 required
Paper clip, standard size
Boiling chips–2 or 3
Stopper, one hole, to fit 18 mm x 150 mm test tube of part A
Tubing, glass, to fit stopper, 10 cm long and bent at 135° angle
Tape, masking, a 5" length
(Scissors, ruler, test tube, test tube clamp, burner of parts A & B)

**TEACHING TIPS**

**Responses to Expect**: Students will ask how the up and down motion of the test tube does anything? Usually, the boys can see the analogy to the piston; the girls may need some help with connecting rods and crank shafts. After reaching question 10, the idea that the burning could take place inside may be proposed.

**Practical Hints**: In part A, see that the inner test tube is low enough that it doesn't fall out when it rises. Caution students not to heat the water too fast. As a precaution against violent boiling, you might want students to put a boiling chip in the larger test tube. Have the interested students cool the outer tube by setting it in cold water to show that the inner tube will come back down.

In parts B and C, you will have to construct a pinwheel for the class to copy. Keep yours and let the teams make their own. In part C, the pinwheel has to be in fairly good balance in order to work; students who don't fold carefully will have to remake theirs. A competitive spirit may arise spontaneously among some students to see who can make the pinwheel that spins fastest.

Patrolling will include looking out for carelessly placed steam jets and for burning pinwheels. Pinwheels can be extinguished with a minimum of fuss by quickly dousing them under the faucet.

**Discussion and Review:** Ask if the class can think of any fuel consuming engines that don't get hot. This will clinch the idea that heated gases expand and move things.

The data in part D, showing the increase in automobiles expected on the roads, will probably fit with increasingly frequent news items about electric or steam cars. We are not working for a cause; let the students draw their own conclusions.

## ENRICHMENT

1. Have a student report on the latest developments in steam or electric cars.

2. Have a student make and demonstrate a simple mechanical model of how the reciprocal motion of the piston is turned into rotary motion.

3. If your area has smog problems, have a student record for a week the daily ozone or other pollution levels reported.

## REFERENCES

### Books

Boumphrey, Geoffrey, *Engines and How They Work,* rev. ed. New York: Franklin Watts, Inc., 1967.

Pella, Milton O., *Physical Science for Progress.* Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1970. Pp. 253-259.

### Multi-Media Aids

*The ABC of the Automobile Engine:* 16 mm film, color, 18 min., General Motors.

*ABC of Internal Combustion:* 16 mm film, color, 13 min., General Motors.

*Does Air Expand and Contract:* 8 mm cartridge plus record, color, 4 min., S.V.E. Standard 8 Cat. No. ST-11R, or Super 8 Cat. No. SU-15R.

*What Makes Engines Go:* Filmstrip, color, 40 frames, Popular Science Publishing Co. Cat. No. 12D

*Fire:* Filmstrip, color, 40 frames, Popular Science Publishing Co. Cat. No. 17A.

*Heat and Work–Engines:* Filmstrip, color, 40 frames, Popular Science Publishing Co. Cat. No. 646.

*Reciprocating Engine:* Overhead transparency, School Products Cat. No. Sc-8274.

*Steam Engine:* Overhead transparency, School Products Cat. No. Sc-8275.

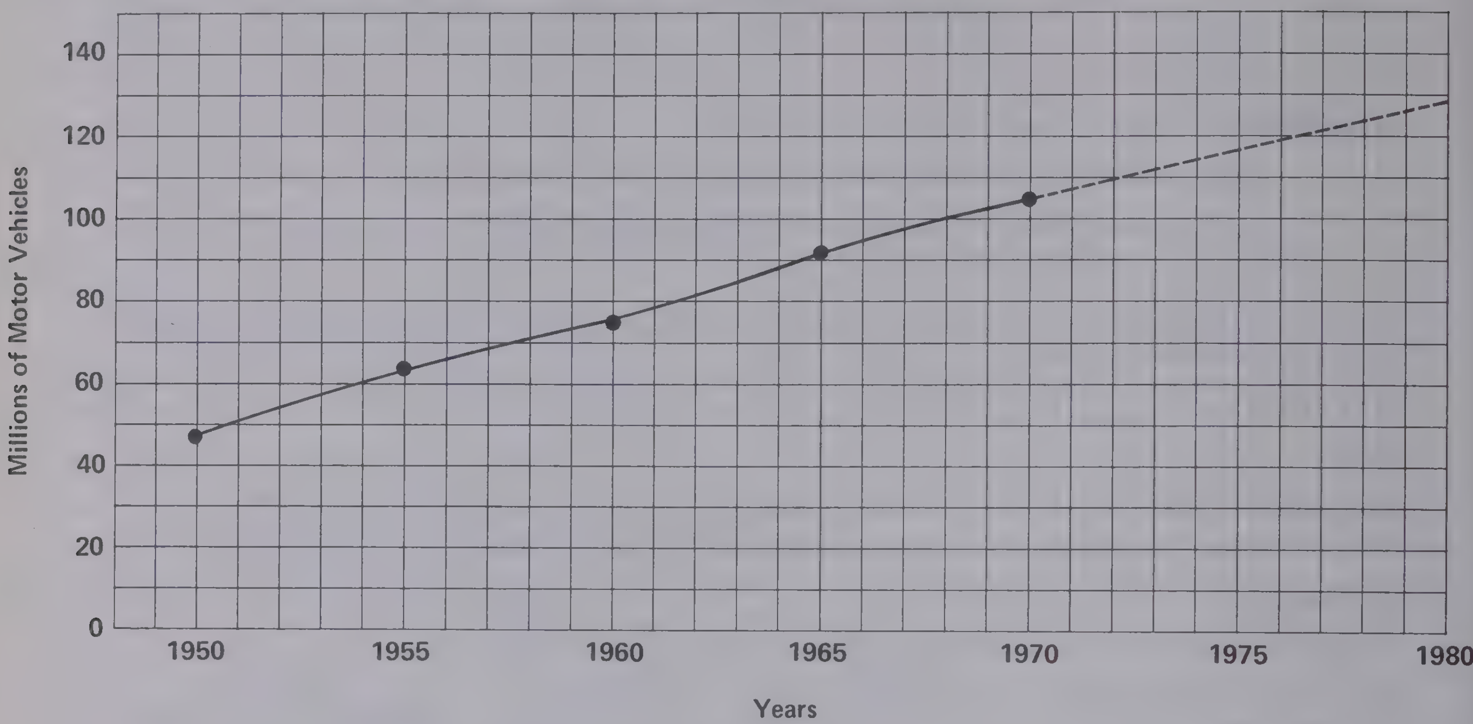
*Internal Combustion Engine:* Overhead transparency, School Products Cat. No. Sc-8276.

## POSSIBLE ANSWERS

1. It burns (or explodes).
2. Students' answers. (They will vary but some boys will come up with some kind of a push on pistons, etc.)
3. (Student measurement: a few millimeters).
4. The smaller tube rises.
5. (Student measurement: one or more centimeters depending upon how long it is heated.)
6. Work.
7. The air expands from the heated water.
8. Heat from burning gasoline makes the gas in the cylinders expand.
9. The pinwheel turns.
10. Work.
11. The pinwheel turns.
12. Heat has caused motion. It did work.
13. The steam turbine.
14. The force of expanding gases turns the vanes of the turbine.
15. Heat made the gas in the test tube expand and push it up.

GRAPH NO. 1

TOTAL MOTOR VEHICLES IN THE UNITED STATES (by 5-year intervals; in millions)




16. Heat made gas expand and push the pinwheel around.
17. Heat makes gas expand and push something.
18. Between 115 million and 125 million.
19. Between 125 million and 135 million.
20. No. It has poisonous gases like carbon monoxide in it. The oxygen is used up.
21. Students' suggestions. (Fewer cars, smaller cars, electric cars, etc.)
22. Some people would be out of work; there might be a depression; etc.
23. Scientific research; laws to control pollution, etc.
24. Expanding hot gas.
25. Expanding hot gas.

**CONCEPT SUMMARY**: Heat from burning fuel expands gases that do work.

## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 6 (1½-2 periods)

**PURPOSE**: Develop the idea that fuels react with something to release heat energy.

**DEVELOPMENT**: (A & B) Flames are observed to die out with a restricted air supply. (C) Chemicals change temperature when dissolved in water.

In each case where energy came from fuel there was an interaction. This dynamic interaction will continue in Idea 4, when we look at the natural environment.

**HIGHLIGHTS**: The paper blocked off from air stops burning (No. 9, page 109).

When chemicals dissolve in water, some of them heat the water but others cool it (No. 14, page 110).

**MATERIALS** (for each team of two)

*Part A—Burning alcohol and paper*
Evaporating dish, small, or 100 ml beaker
Alcohol, ethyl, about 2 ml
Gauze, wire
Petri dish
Paper, about 3" x 3", preferably tissue paper—2 are needed
Cylinder, metal, about 2" x 1" diameter (to serve as platform for burning paper)
Cylinder, graduated, 100 ml

*Part B—Incomplete Burning*
Jar, clear plastic, wide mouth, 1 qt. size

*Part C—Changes in temperature with dissolving*
Thermometer, standard laboratory
Test tube, smaller 13 mm x 100 mm (or other small container to hold about 5 ml of various crystalline solids. Note the 13 mm x 100 mm tube holds about 9 ml)
Beaker, 250 ml
Chemicals, as solids, 5 ml portions: sodium chloride, calcium chloride, sodium carbonate, ammonium chloride, and magnesium sulfate
Water, tap, 500 ml *at room temperature*
(100-ml graduated cylinder from part A)
Paper towels—2 are needed.

**Preparation of Materials**

The alcohol for part A, and the chemicals and room temperature water for part C can be dispensed from a common stock supply placed in a convenient location.

**TEACHING TIPS**

**Responses to Expect**: Parts A and B probably won't be too dramatic. This is not new. Part C is the grabber. Some students won't believe that the solutions can get cooler. They may ask questions, complain, or even falsify data. When they question, your position should be that the data come first and the conclusions must come from it.

**Practical Hints**: Tap water is often much cooler than room temperature. Store sufficient water in the room for several hours in advance so any temperature changes will be due to the chemicals dissolving.

When the students mix the chemicals in the beaker, have them hold the beakers near the top. Lead them to tell you that the heat of their hands would change the water temperature.

As a demonstration, add some concentrated sulfuric acid to water. The rise in temperature is dramatic since the steam fogging the sides of the container may be seen by the whole class. This is too dangerous a reagent to let students use indiscriminately.

**Discussion and Review:** First briefly go through the activity and results. Then begin by asking if there was a time when fuel liberated energy by itself. Finally you will have cornered the class into saying that there is a reaction between fuel and something else every time heat energy is liberated to do work.

## ENRICHMENT

1. Interested students will want to try other chemicals to see if they become hotter or colder on dissolving. Look through the heat of solution tables in the *Handbook of Chemistry* for chemicals that will either warm up or cool down by significant amounts.

2. Have a student demonstrate a can of self-heating shaving cream and explain why it gets hot. The answer is that peroxides or similar compounds react with the air.

3. Have a student report on rocket fuels, including pyrogallic fuels that ignite upon mixing with the oxidizer.

4. Students who fly powered model airplanes can report on the various fuel mixtures they use.

## REFERENCES

### Books

Blackwood, Paul E., *Push and Pull: The Story of Energy,* rev. ed. New York: McGraw-Hill Book Co., 1966.
DeCamp, L. Sprague, *Man and Power.* New York: Golden Press, Inc., 1961.
Sterland, E. G., *Energy Into Power.* Garden City, N.Y.: Natural History Press, 1967.

### Multi-Media Aids

*Energy Conversion:* Super 8 cartridge, silent, color, 4 min., Ealing Cat. No. 80-3437/1.
*Fire Science:* 16 mm film, color, black and white, 15 min., Churchill.
*Fuels: Their Nature and Use:* (2nd ed.) 16 mm film, black and white, 11 min., E.B.F. Film No. 1609.
*Heat: Its Nature and Transfer:* (2nd ed.) 16 mm film, black and white, 11 min., E.B.F. Film No. 1608.

## POSSIBLE ANSWERS

1. Students' predictions. (Some may know that burning is a chemical change.)
2. Light and heat.
3. Nothing, or a little water.
4. It is smooth, thin, white. It makes crackly noises when crumpled. It holds together unless you tear it on purpose.
5. Light, heat, and smoke.
6. It is black, soft, and has no special shape. It falls apart if you touch it.
7. No. Its properties are different.
8. No. We can't see the air around the paper.
9. The fire goes out when the air is cut off. The water rises.
10. Part of the original tissue paper and part of the ash. Also smoke.
11. Air.
12. Air is reacting with the fuel.
13. Energy.
14. The data table should show a temperature rise for some chemicals, but a fall for others.
15. Sometimes it was released; other times it was absorbed.
16. None.
17. When the fuel reacts with something in the air.
18. (Depends upon the student's prediction; most will claim at least partial success.)

**CONCEPT SUMMARY:** Fuels release energy by reacting with other matter.

## PHYSICAL SCIENCE IDEA 3; ENERGY, Investigation 7 (2 periods)

**PURPOSE**: Introduce the concept that the primary source of energy is the atom.

**DEVELOPMENT**: (A) Students will use a hot nail and a radioactive substance to expose film and thereby to establish radiation as energy. (B) They will use a solar cell to turn an electric motor, and (C) use dominoes to simulate a nuclear chain reaction.

**HIGHLIGHT**: Both the sample and the hot nail have left an image on the film (No. 3, page 112).

**MATERIALS** (for each team of two)

*Part A–Radioactive exposure of film*
Film, 1 sheet, 4" x 5", wrapped in flexible plastic envelope
Materials to develop the film:
  developer, a few grams
  fixer, a few grams
  syringe, to add and remove developer and fixer solutions from the plastic envelope
Nail, 5" long
Cork, to hold the heated nail
Chalk, small piece
Radioactive sample, sealed 50 microcurie beta emitter
Burner
Gauze, wire
Tape, masking, a few inches
Cardboard, manila folder type, 2" square

*Part C–Chain reaction*
Dominoes, set of

**MATERIALS** (for the class)

*Part B–Solar cell*
Solar cell
Motor, small electric

**Preparation of Materials**

For part A, Hickok Teaching Systems will supply photographic film that can be both exposed and developed in the undarkened classroom. You can also obtain this film directly from Atomic Corporation of America, 7901 San Fernando Road, Sun Valley, California 91352. The film from these suppliers comes in single sheets of 4" x 5" film wrapped in an opaque, flexible plastic envelope. The radioactive source is taped to this envelope to expose it. The exposed film is then developed by adding and removing the developing solutions through a small hole poked through the envelope. Complete instructions come with the film.

A 50 microcurie beta emitter is a convenient radioactive source that will provide ample exposure in 24 hours.

Rather than dispensing small quantities of developer and fixer to teams, and having them make up their own solutions, you may want to make up class quantities: count on about 20 ml of each per team.

NOTE THAT FILM DEVELOPING CHEMICALS SHOULD BE HANDLED RESPECTFULLY. IF ANY GET ON SKIN OR CLOTHING THEY SHOULD BE RINSED OFF IMMEDIATELY.

If photography puzzles you, stop at the local camera shop; sales personnel at these stores frequently are happy to supply information.

It is suggested that you have students tape the radioactive sample to the film envelope about one or two days before you expect to start the investigation. When they do this, don't attempt to explain to them just why they are doing it, other than to say that they are getting ready for the following investigation.

## TEACHING TIPS

**Responses to Expect**: How dangerous are the radioactive samples? The students have seen them before but radioactivity still has an aura of mystery. The samples are safe as long as they stay sealed and are kept away from prolonged close contact with the body.

**Practical Hints**: Keep track of the radioactive sources. There isn't much one can do, but some students are intrigued enough with them to want to hold on to them.

The heat source, either nail or soldering iron, should make the paper smoke but not burn so much that the film is destroyed or that light may enter.

When this investigation is started, the introductory reading and discussion could lead to the point where the hot nail is applied, then the sample is removed (and collected) and the film developed.

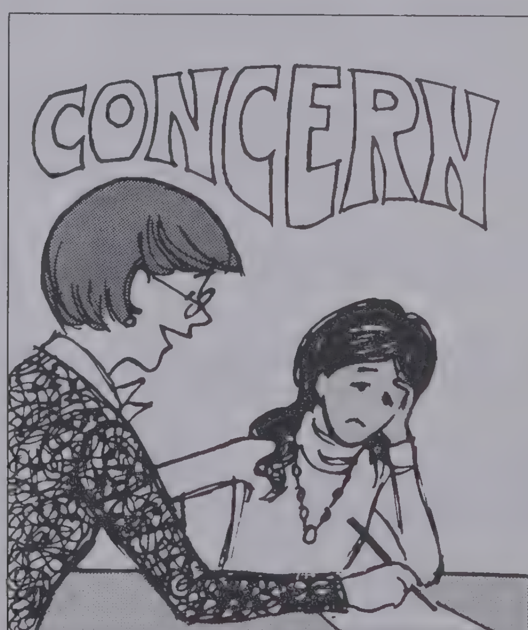
Have some previously developed film around in case some groups have trouble developing their film. Thus they can see what the film should look like.

**Discussion and Review**: Most students will have heard of atomic energy, even though these are only words. The fact that this energy can do something, even so trivial as exposing film, is proof of its existence. Enough radioactive material to show a measurable temperature rise would be far beyond the facilities of a classroom.

It may come as a surprise to some that the energy we derive from food originates in nuclear reactions within the sun, and that therefore the nucleus is our ultimate source of energy.

## ENRICHMENT

1. Have students report on Project Sherwood or Project Plowshare, the peaceful uses of nuclear energy.
2. Have a student perform other versions of chain reaction analogies, with mouse traps, matches, or whatever else students may improvise.
3. Have a student panel discuss possible effects of a limited hydrogen supply for the sun.



## REFERENCES

### Books

Fermi, Laura, *The Story of Atomic Energy.* New York: Random House, 1961.

Haber, Heinz, *Our Friend the Atom.* New York: Golden Press, 1968.

*Project Plowshare.* Public Affairs Press, Washington, D.C., 1962.

### Multi-Media Aids

*Basic Principles of Power Reactors:* 16 mm film, color, 8½ min., A.E.C.

*Controlling Atomic Energy:* 16 mm film, color, 13½ min., A.E.C.

*Introducing Atoms and Nuclear Energy:* 16 mm film, color or black and white, 11 min., A.E.C.

*Nuclear Powered Steam Turbine Generator:* Transparency, color, Universal Educational and Visual Arts Cat. No. UT 1609.

## POSSIBLE ANSWERS

1. (While answers will vary, most students will say something about atoms.)
2. Light.
3. There are light spots (images) where the specimen was taped and where heat was applied.
4. It exposed the film (caused light spots).
5. It exposed the film (caused light spots).
6. The sun.
7. The motor only turns when the sun hits the cell.
8. It takes energy to run the motor. The motor only ran when the sun hit the cell.
9. Satellites, some telephone systems way out in the country.
10. None.
11. The sun.
12. A chain reaction.
13. The first one knocks down two which knock down three until they are all down. (A chain reaction.)
14. In each case when one thing reacts, it makes other things react. (One domino knocks over two more; maybe one atom sets off two more.)
15. They are afraid of radioactivity and accidents.
16. Students' answers. (These will vary with current news, previous information, and each student's image of atomic energy.)

**CONCEPT SUMMARY**: Energy comes from interacting nuclei of atoms.

## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 8 (2-2½ periods)

**PURPOSE**: Introduce the problems and tentative solutions to radiation hazards and safety.

**DEVELOPMENT**: Students will observe changes in the intensity of radiation (A) as the distance between sample and detecting device is varied, and (B) as the amount of cardboard placed in front of the detector is varied.

The hazards of radiation will be brought up in connection with nuclear power reactors.

**HIGHLIGHT**: Radiation activity increases sharply at small distances from the sample (No. 9, page 117).

**MATERIALS** (for the teacher)

*Part A–Radiation intensity and distance*
Meter stick
Radioactive sample, sealed, 50 microcurie beta emitter
Geiger tube
Power supply, high voltage to operate Geiger tube
Audioamplifier and speaker to display Geiger tube's response
Clock with a second hand

*Part B–Radiation intensity and shielding*
Cardboard, such as is used for scratch pad backing, 2" square–32 pieces needed
Tape, masking, a few inches

**Preparation of Materials**

If you haven't radiation detection equipment, you can probably borrow it from the physics teacher of a local high school or from Civil Defense personnel. They may be able to send someone in to demonstrate use of the equipment. If you cannot obtain help from these persons, the teacher may inform students of the results to be expected in parts A and B.

**TEACHING TIPS**

**Practical Hints**: If more sophisticated equipment, such as counters or rate meters, is available, change the procedure to substitute rate meter readings (or radiation level readings) in the table or on the graph.

**Discussion and Review**: The data will speak for itself. The effects of distance and shielding are obvious. Use this discussion to drive toward the complexity of final decisions due to cost, space, weight, and other factors.

The debate over testing flares up from time to time as noncooperating countries still fire an occasional bomb. Our underground testing makes headlines when Las Vegas resort owners try to stop it by legal action.

A new area of concern is the proliferation of power reactors. The books in the reference section are intended more for the teacher than the students. The one on reactor problems is a source of much comment and agitation.

**ENRICHMENT**

Have a student report on safety regulation for radioactivity.

Have an artistically inclined student illustrate some of the more sensational material in *The Careless Atom* with flip charts or simple population-reactor maps.

Get a conservation group or Civil Defense group to provide a speaker or demonstration.

Invite your local power company to come into the classroom with their side of the reactors-are-necessary argument.

## REFERENCES


### Books and Articles

Fowler, John M., ed., *Fallout.* New York: Basic Books, Inc., 1960.

Novick, Sheldon, *The Careless Atom.* Boston: Houghton Mifflin, 1969.

Pirie, Antoinette, ed., *Fallout,* 2nd ed. London: MacGibbon and Kee, 1958.

Pauling, Linus, *No More War,* rev. ed. New York: Apollo Editions, Inc., 1962.

*U.S. News and World Reports.* Sept. 2, 1963. (Teller's arguments for continued testing).

### Multi-Media Aids

*The Mighty Atom:* 16 mm film, sound, color, 27 min., A.E.C.

*Living with Radiation:* 16 mm film, sound, color, 28 min., A.E.C.

*Living with the Atom:* 16 mm film, sound, color, 18 min., A.E.C.

*Radiation and the Population:* 16 mm film, black and white, 29 min., A.E.C.

*Radioactivity:* Super 8 cartridge, silent, color, 4 min., Ealing Cat. No. 80-3346/1.


## POSSIBLE ANSWERS

1. Students' answers. (They are usually sophisticated enough to think of some version of atomic or solar energy.)
2. Students' answers. (Wide variation, from lead suits to shelters.)
3. No; the pulses are too rapid to count.
4. Students' data. (This will depend on the activity of the sample.)
5. Students' data.
6. No; pulses are too rapid.
7. (Depends on students' graphs.)
8. Doesn't change much (as determined by subtracting counts/minute at 60 cm from counts/minute at 20 cm.)
9. Changes a great deal (as determined by subtracting counts/minute at 10 cm from extrapolated counts/minute at 0 cm).
10. (At the closest distance for which the student's graph is still relatively flat.)
11. Radioactivity gets much greater at closer distances.
12. Avoid getting near radioactive matter.
13. The cardboard cuts down the amount of the radiation.
14. Students' answers.
15. (From student's graph. This may resemble the other graph depending upon the source used.)
16. (Depends on student's graph.)
17. (Student's graph. It may resemble the first graph, depending upon the source used.)
18. The thicker the shield the better.
19. Metals, wood, plastics, etc.
20. Each pulse corresponds to a particle or group of particles flying out of radioactive atoms.
21. Buy a large piece of cheap land and build the reactor at the center of it.
22. Use concrete; the space is cheaper than the few inches saved.
23. Use lead; space on a submarine is so crowded the cost is less important.
24. Students' answers. (Look for a decision based on data, rather than a "right" answer.)

**CONCEPT SUMMARY**: Radiation safety depends upon shielding, and distance from the radioactive material.

## PHYSICAL SCIENCE IDEA 3: ENERGY, Investigation 9 (1½ periods)

**PURPOSE**: Establish that matter can be converted into energy when particles interact.

**DEVELOPMENT**: (A) The weights of an interacting neutron and uranium atom will be compared to the weights of the fission products. From this, students will see that matter seems to disappear. (B) A similar comparison will be made for the interaction of four hydrogen atoms to form a helium atom fusion product.

The disappearing matter is accounted for in the energy released by these reactions. All energy changes require that two or more particles interact.

**HIGHLIGHTS**: The average amount of matter per particle gradually drops and then rises as the mass numbers increase (No. 1, p. 122).

The remains of nuclear reactions don't weigh as much as the original materials (No. 4, page 122, and No. 8, p. 123).

**MATERIALS** (per class)

Scratch paper

**TEACHING TIPS**

**Responses to Expect**: Students will protest: "This isn't a math class, etc." The answer is not that math is wonderful, but: "A scientist uses whatever tools he can to solve a problem and math is one of his most important tools."

**Discussion and Review:** Discussion centers on the disappearing matter and the fact that particles interact. It will take guidance to answer question 5 (What explanation can you give for the loss in weight?) without just telling the answer. You might say something like, "If matter has disappeared, what do you think became of it?" or "What could matter turn into?"

Einstein's idea of the equivalency of matter and energy will take a more direct approach.

Some student may complain that the amount of matter lost is so small, a few hundredths of a unit, that he can't see where the energy comes from. Write out Avogadro's number, 602 plus 21 more zeros and say that is the number of hydrogen atoms in one gram. If the whole gram turned into helium there would be a fantastic amount of energy. String the zeros across the board as dramatically as possible.

For the windup, keep coming back to the theme of the last few questions, the fact that the energy only shows up when there are interactions.

**ENRICHMENT**

1. Have a student report on why iron, at the bottom of the curve, would be a poor choice for an atomic energy fuel.

2. Have a student panel discuss the pros and cons of power reactors in populated areas.

3. Proponents of power reactors claim they would aid the fight against air pollution. Have a debate on this positive value versus the negative effect of both increased radioactivity and heat (thermal) pollution.

4. Get a student to report on the problems of radioactive waste disposal.

**REFERENCES**

**Book**


Zinn, W.H., F.K. Pittman, J.F. Hagerton, *Nuclear Power, U.S.A.* New York: McGraw-Hill Book Co., Inc., 1964.


**Multi-Media Aids**

*The Atom and Eve:* 16 mm film, color, 15 min., A.E.C.

*Atomic Power Production:* 16 mm film, color, 14 min., A.E.C.

*Snapshot:* 16 mm film, color, 19 min., A.E.C.

*Tomorrow's Power–Today:* 16 mm film, color, 5½ min., A.E.C.

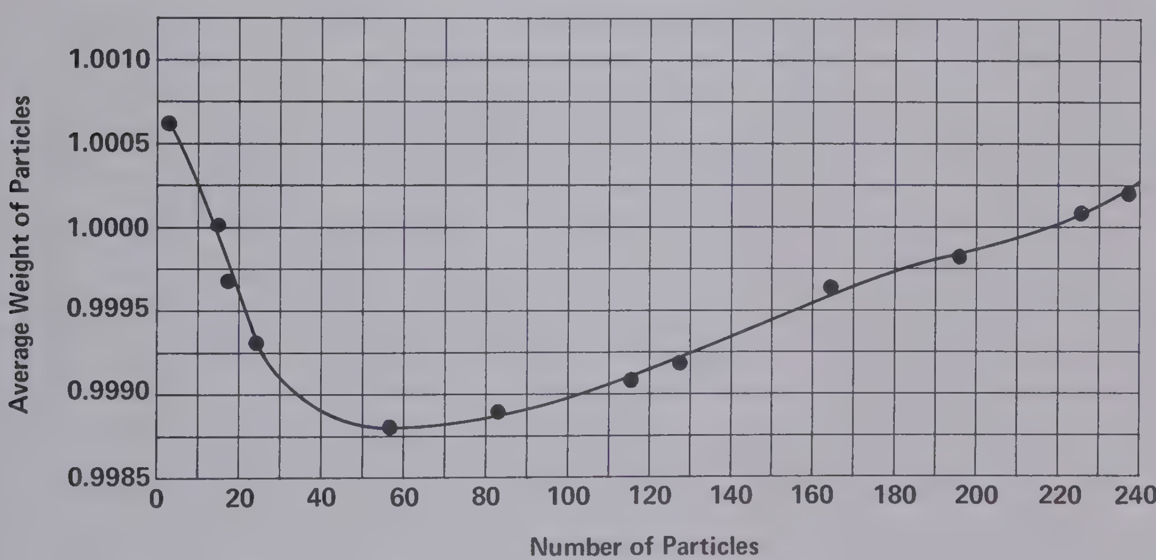
*Using Atomic Energy for Electric Power:* Filmstrip, 40 frames, silent, color, Popular Science Publishing Cat. No. 568.

**POSSIBLE ANSWERS**

1. The graph drops sharply (going from left to right) and then gradually climbs.

GRAPH NO. 1

AVERAGE WEIGHT OF NUCLEAR PARTICLES IN SELECTED ATOMS




2. 236.0528 units.
3. 235.8285 units.
4. The remaining particles weighed less.
5. Something happened to the matter.

6. Early 1900's.
7. 4.0312.
8. The helium is lighter than four hydrogen atoms.
9. The elements at the ends of the graph.
10. No; a neutron hit it.
11. At least two.
12. More than one.
13. Matter and energy are closely related. Energy is released when particles of matter interact.

**CONCEPT SUMMARY**: Interacting particles release or absorb energy.

**IDEA SUMMARY**: When particles of matter interact, energy may be either released or absorbed.

# Idea 4
## Interaction

In Idea 4, the concepts move away from abstraction to the more familiar. In a dozen concepts students discover that:

MATTER AND ENERGY ARE CONSTANTLY INTERACTING TO PRODUCE OUR CHANGING ENVIRONMENT.

Earth science is often included in science courses as isolated units of geology, meteorology, and astronomy. Here the important concepts are tied together with the unifying theme of interacting matter and energy.

The first concept is that of change. Then matter-energy interactions are found to cause wind. The interactions are extended to moisture in the air. Energy as a cause of erosion is developed. The reverse action of building new layers is also discovered, as is the action of energy raising and lowering the surface of the Earth. Investigation 8 shows how energy transmits information throughout the Earth. The last four investigations explore matter and energy in space, encompassing such concepts as seasonal variation, measurement of distance by triangulation and parallax, and spectroscopy as used to analyze nonterrestial matter.

Once again reading through the whole Idea in advance will pay off in planning your time, anticipating student reactions and preparing the materials needed for each of the investigations.

## PHYSICAL SCIENCE: IDEA FOUR (INTERACTION)

### Matter and Energy Are Constantly Interacting, Producing Our Changing Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. NOTHING IS FOREVER | Our surroundings are constantly changing. | Inspecting weather maps, sunspot photos, and moon photos |
| 2. IT'S A BREEZE | Interacting heat energy and air cause wind. | Heating sand and water by radiation; blowing up a balloon with hot air; the Coriolis effect |
| 3. IT'S NOT THE HEAT; IT'S THE HUMIDITY | Moisture in the air is controlled by interacting water, air, and energy. | Evaporating and condensing water; forming fog in a jar |
| 4. WE WALK ON IT DAILY | Interacting matter and energy wear away the surface of the earth. | Cracking a jar by freezing water; fracturing plaster by embedded beans; reacting lemon juice with calcite |
| 5. OUR GREAT BIG LAYER CAKE | Interacting matter and energy form new layers of the earth's surface. | Evaporating copper sulfate solution; examining fossils; forming sedimentary layers in a milk carton |
| 6. GROW SOME ROCKS | Interacting matter and energy form new materials in the earth. | Melting, dissolving, and recrystalizing crystals; forming an insoluble substance by combining a soluble crystal with sodium silicate |
| 7. WHAT GOES DOWN MUST COME UP | Interacting matter and energy raise and lower the surface of the earth. | Inspecting marine fossils from mountains; melting ice allowing floating board to rise; demonstrating isostasy in silly putty using metal cylinder |
| 8. WHAT'S GOING ON DOWN THERE? | Energy waves give information about the earth. | Sending waves through springs; interpreting seismograph records |
| 9. IT GETS LATE TOO EARLY | The amount of radiant energy reaching the earth changes regularly with time. | Analyzing fuel bills; measuring sun's angle; studying average temperatures |
| 10. SOMEWHERE IN SPACE | Energy from objects in space is used to locate them. | Measuring angles and distances with range finder; parallax |
| 11. THE STARS TELL ALL | Energy from objects in space is used to tell what they are made of. | Heating objects to incandescence; seeing through a prism the spectrum of ordinary light; observing through a grating solid and gaseous spectra |
| 12. TURN RIGHT FOR SUNSHINE | The moving earth causes the energy changes that produce the seasons. | Illustrating the seasons at different latitudes with a sphere |

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 1 (1 period)


Find out the time of sunset for the previous day as well as the day you do this investigation.

**PURPOSE**: Make students aware that our natural surroundings are continually changing.

**DEVELOPMENT**: From photographs in the text, students will note changes caused by (A) flood and earthquake, and changes in (B) weather, and (C) time of sunset and the moon's phases.

This investigation will emphasize the fact that there are changes continually occurring in our natural environment.

**HIGHLIGHT**: The surface of the Earth moves about (No. 3, page 126).

**MATERIALS**

None

**TEACHING TIPS**

**Practical Hints**: Mention to students that they are starting a new idea. The format of this Idea is the same as the others: a series of concepts will be drawn together to build the Idea. The interaction of matter and energy is used to unify different aspects of earth science.

In part B, augment the material by using the school copying machine to make transparencies of daily weather maps from the local newspaper. Explain the symbols if asked. Don't make the explanation a lecture. You are showing the maps to point out daily changes.

Students may want to know the names of the moon's phases. The only unfamiliar one would be between half and full moon. This is called "gibbous."

Take advantage of any natural disaster (flood, tornado, earthquake, or hurricane) to point up the unstable nature of our surroundings.

You will have to evoke some response for student curiosities in number 14. (List some questions scientists might ask about the action going on around you.) To get the ball rolling, call first on a student you are sure of.

**Discussion and Review**: Students at this age level are aware of change. Change, in fact, is the teen rallying cry. Here we are looking at changes that are indifferent for the most part to man and his activities.

Your leading questions are the clue leading students to the conclusion that their natural environment is constantly changing.

## ENRICHMENT

1. In a darkened room have a student explain the phases of the moon—using white balls for the earth and moon, and a single light source for the sun.

2. A student who is a reader may want to report on great natural disasters, old ones such as occurred at Lisbon or Port Royal, or more recent ones such as have occurred in Alaska, Chile, and Peru.

3. A student with a telescope could project images of the sun on a piece of paper to inspect it for sunspots.

DANGER: STUDENTS SHOULD NEVER LOOK AT THE SUN THROUGH TELESCOPES OR BINOCULARS OR WITH THE UNPROTECTED EYE. THIS CANNOT BE STRESSED TOO STRONGLY. THE DAMAGE IS QUICK AND PERMANENT.

## REFERENCES

### Books


Johnson, Thomas P., *When Nature Runs Wild.* Mankato, Minn.: Creative Educational Society, 1968.

Thorarinsson, Sigurdur, *Surtsey: The New Island in the North Atlantic.* New York: Viking Press, 1967.

Tufty, Barbara, *1001 Questions Answered About Natural Land Disasters.* New York: Dodd, Mead & Co., 1969.


### Multi-Media Aids

1. *The Earth: Changes in Its Surface:* 16 mm film, color, 11 min., Coronet Cat. No. 1277.
2. *The Great Weather Mystery:* 16 mm film, black and white, McGraw-Hill Cat. No. 618064.
3. *How Solid Is Rock:* 16 mm film, color, 22 min., EBF Cat. No. 2584; B/W: Cat. No. 2585.
4. *The Inconstant Air:* 16 mm, sound, color, 27 min., McGraw-Hill Cat. No. 68117, B/W: Cat. No. 681104.
5. *Weather Information Map:* Transparency, silent, School Products Cat. No. Sc-8394.

## POSSIBLE ANSWERS

1. Students' answers. (Either land sank or water rose.)
2. The ground crumbled, the foundation was not good, etc.
3. It is changing.
4. It has moved to the east.
5. About 3.
6. It keeps changing.
7. (Check with forecast in paper or with weather bureau.)
8. (Check as above.)
9. (The students' answer will depend upon whether the days are growing longer or shorter.)
10. Students' answers. (They may not have noticed.)
11. The shapes all seem different. (Different phases.)
12. Looking at the three pictures from left to right: The light area at the top is growing larger. The dark band going across the center is getting smaller.
13. They change.
14. Students' answers. (What causes the environment to change? How rapidly does it change? etc.)

**CONCEPT SUMMARY**: Our surroundings (environment) keep changing.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 2 (2½-3 periods)

**PURPOSE**: Show how heat energy interacts with air to produce wind.

**DEVELOPMENT**: Students will measure temperature changes (A) of sand and water when equal masses are heated for equal times and (B) of sand samples heated by light striking them at different angles. They will (C) heat a test tube having a balloon over its mouth and (D) observe the downward movement of Dry Ice vapor. (E) They will see that a hand dropping sand while moving along the radius of a circle will produce a curved sand trail if the circle is revolving.

The various activities will demonstrate that the atmosphere is a mechanism kept in motion by the sun's energy.

**HIGHLIGHTS**: The sand heats up faster than the water (No. 3, page 132).

The sand makes a curved path on the rotating table (Nos. 28 & 29, page 136).

**MATERIALS** (for each team of two)

*Part A–Heating sand and water*
Sand, 400 ml
Pan, pie, aluminum, disposable, 7" diameter
Balance, platform
Thermometer, standard laboratory
Burner
Socket with 6 foot lampcord and plug
Bulb, 100 watts, or 75 to 150 watt spotlight bulb
Support, for pie pan (ring stand, ring, wire gauze, etc.)

*Part B–Heating a surface from different angles*
(Socket with 6 foot lampcord and plug from part A)
(Bulb, 100 watts, or 75 to 150 watt spotlight bulb from part A)
Meter stick
Protractor
(Balance, thermometer, pie pan and sand of part A)

*Part C–Heat expands a balloon*
Test tube, Pyrex, 18mm x 150mm
Burette clamp or test tube clamp
Balloon
(Burner from part A)
Ice, 30 g

*Part D–Cold air falls*
Dry Ice, size of a grape
Beaker, 100 ml

**MATERIALS** (for the class)

*Part D–Pouring sand on a revolving disc*
Turntable–lazy Susan will work well
Cardboard disc, 18 inch diameter
Sand, 50 ml

**Preparation of Materials**

If Dry Ice is a problem, try a local ice cream distributor. Do not let students handle it with bare hands. In the place of Dry Ice used in part D to demonstrate the density of a gas at different temperatures, you might want to use the following procedure:

Take a piece of rubber tubing 3 or 4 feet long with a small internal diameter (1/8 to 1/4 inch). Coil it inside a 600 or 1000 ml beaker so that both ends hang out over the edge.

Do this with a second beaker and a second piece of tubing. Half fill one beaker with ice water, the other with hot water.

Have two students blow smoke through each piece of tubing, and have the class observe the difference in the way the cool air and warm air behave.

Pose the question: Which is heavier, cool air or warm air?

## TEACHING TIPS

**Responses to Expect**: Expect questions about the difference in heating sand and water. There are two things involved, the fact that only the sand surface is heated and that it takes more heat to warm a gram of water than a gram of sand.

**Practical Hints**: You may want to spread newspaper on the lab tables to make cleaning up spilled sand simpler. Don't make housekeeping too important. Students get enough of that as it is.

Some students will still need help in reading thermometers. Watch that they don't take the thermometers out of the sand or water to read them. These students have had most of their experience with clinical thermometers and don't realize laboratory thermometers won't hold a reading.

The procedures are best explained part by part, just prior to being begun. Explain them to the entire class at one time; or, if your groups work at different speeds and there are not too many of them, to each group individually as the need arises.

Caution students about touching hot bulbs.

**Discussion and Review**: As the class shifts from data taking to discussion, emphasize by your leading questions that most of their activity was either adding or removing energy from matter.

Then discuss the atmosphere. Here the gain or loss of energy accounts for air motion, or wind.

The turning of wind or Coriolis force is illustrated in the Bell Telephone film *Unchained Goddess* (contact the local telephone office). This is an hour-long film in two reels, which might be split between this and the next investigation.

## ENRICHMENT

1. Have an alert student measure the temperature change when he adds hot sand to an amount of water. Then have him add an equal weight of hot water and see what the temperature change will be.

2. Have a student keep records on which way the school flag is blowing morning and evening for a period of time. See if he can correlate this with known weather phenomena, such as prevailing westerlies or the wind shifts when a front passes through.

## REFERENCES

### Books

Henry, Bernard, *Air.* New York: Roy Publishers, Inc., 1969.

Lehr, Paul E., *Storms: Their Origins and Effects.* New York: Western Pub. Co., Golden Paperbacks, 1969.

Rosenfeld, Sam, *Science Experiments with Air.* Irvington-on-Hudson, N.Y.: Harvey House, Inc., 1969.

Shuttlesworth, Dorothy E., *Clean Air, Sparkling Water.* Garden City, N.Y.: Doubleday & Co., Inc., 1968.

Slote, Alfred, *Air in Fact and Fancy.* Cleveland: World Publishing Co., 1968.

Winchester, James H., *Hurricanes, Storms, Tornadoes.* New York: G.P. Putnam's Sons, 1968.

**Multi-Media Aids**

*Air Expansion by Heat:* 8 or super 8 loop, silent, color, 3½ min., EBF Cat. No. 80742.
*Air Pollution and Cars:* 16 mm film, black and white, 16 1/2 min., General Motors.
*Atmosphere and Its Circulation:* 16 mm film, black and white, 11 min., EBF Cat. No. 237.
*Big Winds–the Destroyers:* Film strip, silent, color, 40 frames. Popular Science Publishing Cat. No. 585.
*The Earth: Its Atmosphere:* 16 mm film, color or black and white, 11 min., Coronet Films Cat. No. 1298.
*The First Mile Up:* 16 mm film, black and white, 28 min., McGraw-Hill Cat. No. 672320.
*Unchained Goddess:* 16 mm film, color, 60 min., Bell Telephone.
*What Makes the Wind Blow:* 16 mm film, 16 min., EBF Color: Cat. No. 2249, B/W: Cat. No. 2250.
*Why Air Circulates:* 8 or super 8 loop, silent, color, 3½ min., EBF Cat. No. 80740.
*Why Does the Wind Blow:* Film strip, silent, color, S.V.E. Cat. No. 421-1.


**POSSIBLE ANSWERS**

1. Students' answers. (Water is cooler; water absorbs heat, etc.)
2. The temperature rose.
3. The sand temperatures were higher.
4. Over the sand.
5. The sand cools faster.
6. Over the water.
7. In the desert.
8. In Omaha.
9. In Omaha.
10. Near the sea.
11. The angle of sunlight. (The height of the sun, etc.)
12. The higher the angle the higher the temperature.
13. More heat is received at the Equator.
14. Students' answers. (Expand, rise, etc.)
15. The balloon swells up.
16. The balloon goes down (crumples, deflates, etc.).

17. The balloon flattens out more (moves into the flask).
18. It expands (swells up).
19. It contracts (pulls in).
20. The pressure goes up.
21. The vapor rolls down the side of the container. (It falls to the floor, etc.)
22. It is heavier.
23. The heavy one pushes away the light one.
24. Toward the land.
25. The heavy cold air falls to the valley bottom.
26. Students' answers.
27. A straight line.
28. A curved line.
29. It curves the other way.
30. In a curved line.
31. In a straight line North to South.
32. Kansas City is in the tornado belt.
33. Heats it (gives it heat energy).
34. Energy.
35. Students' answers. (Hopefully affirmative at this point.)

**CONCEPT SUMMARY**: Heat energy and air interact to cause wind.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 3 (2 periods)

**PURPOSE**: Develop the concept that moisture in the air is controlled by the interactions of heat, water, and air.

**DEVELOPMENT**: (A) Students will observe the cooling effect on their hands of evaporating water, and they will observe the condensing of (B) water vapor and (C) steam on a cold metal cup.

The change of state of water will be seen as another interaction of matter and energy.

**HIGHLIGHTS**: The moving wet hand gets colder (No. 2, page 138).

Fog forms in the cooled jar (No. 6, page 139).

**MATERIALS** (for each team of two)

*Part A–Evaporating water by boiling*
Beaker, 100 ml or evaporating dish
Burner
Support for beaker (ring stand, ring, wire gauze)

*Part B–Condensing water vapor on a metal cup*
Cup, metal, 8 oz. (tin can will do)
Ice, 2 or 3 ice cubes
Jar, clear plastic, wide mouth, 1 qt.
Wood splint
Cheesecloth
String, 6" length

*Part C–Condensing steam on a metal cup*
Flask, Erlenmeyer, 250 ml
Stopper, one hole, to fit flask
Glass tubing, to fit stopper, 4" long, right angle bend in the middle
Boiling chips–2 are needed
Thermometer, standard laboratory
Support for flask (ring stand, ring, wire gauze, burette clamp)
Support for metal cup
(Burner and metal cup from parts A and B)

**Preparation of Materials**

Have the glass tubing inserted in the stoppers in advance.

**TEACHING TIPS**

**Responses to Expect**: Expect a little silliness or diffidence about waving a wet hand around. Also expect questions about smoke, clouds, and fog, and how do clouds form over the ocean where there is no smoke. The answer to the last question: Clouds form on salt crystals from evaporated ocean spray. There have been efforts to correlate rainfall with meteor showers but the results are not in yet.

**Practical Hints**: In part A, watch for students who heat the beaker or evaporating dish after it's gone dry. In part C, caution students against burning themselves with steam.

You will have to use leading questions with the fog in the jar. The first trial usually doesn't work. It will take time to lead students to thinking of smoke particles as solids in the air. Some may want to try dust or other materials. Here is a chance to allow some experimentation. The smoke from a glowing splint usually works well. You may have a demonstration device consisting of a glass flask with a rubber bulb that uses smoke to make a fog. Welch Scientific calls it a Cloud Forming Apparatus, catalog number 1730. Don't use it until the students have done their experiment.

**Discussion and Review:** Keep in mind that the theme is the interaction of energy and matter, with special emphasis upon the changes of state of water. The theme will continue throughout the Idea, as it relates to the atmosphere, the earth, and space. The problems of weather control and its complications may involve some students in free discussion.

## ENRICHMENT

1. A student interested in aircraft can report on icing problems as an example of a solid encountering super-cooled liquids.

2. Have a set of cloud pictures for those students interested in identifying the different types.

3. Have a student explain why lakes appear to steam under some weather conditions.

## REFERENCES

### Books and Article


Carlson, Carl and Bernice, *Water Fit to Use.* New York: John Day Co., 1966.

Ehrlich, Dr. Paul, "Eco-Catastrophe," *Ramparts Magazine,* Sept. 1969, 8:24-28, No. 3.

Halacy, D.S., *The Water Crisis.* New York: E. P. Dutton & Co., Inc., 1966.

Halacy, D. S., *The Weather Changers.* New York: Harper & Row, 1968.

Hellman, Hal, *Light and Electricity in the Atmosphere.* New York: Holiday House, Inc., 1968.

Helm, Thomas, *Hurricanes: Weather at Its Worst.* New York: Dodd, Mead & Co., 1967.

U.S. Department of Interior, *The Third Wave . . . America's New Conservation.* U.S. Government, 1967.

van Straten, Florence W., *Weather or Not.* New York: Dodd, Mead & Co., 1967.


### Multi-Media Aids

*Condensation of Water Vapor:* 8 or Super 8 loop, silent, color, 3½ min., EBF Cat. No. 80736.

*Formation of a Cloud:* 8 or Super 8 loop, silent, color, 3½ min., EBF Cat. No. 80737.

*Water Conservation:* Film strip, silent, color, 40 frames, Popular Science Publishing Cat. No. 560.

*The Water Cycle:* 16 mm film, black and white, 11 min., EBF Cat. No. 366.

*Water Cycle:* Transparency, School Products Cat. No. Sc-8398.

*Water for the Community:* 16 mm film, color or black and white 11 min., Coronet Cat. No. 1152.

*Weather Fronts and Forecasting:* Film strip, color, 40 frames, Popular Science Publishing Cat. No. 564.

*What Makes Clouds:* 16 mm film, 19 min., EBF Color: Cat. No. 2251, B/W: Cat. No. 2252.

*Working Water:* 16 mm film, color, 14 min., Bailey Cat. No. 16-394.

POSSIBLE ANSWERS

1. The moving hand is drier.
2. The moving hand is cooler.
3. It is gone (evaporated, boiled out, etc.)
4. The cup gets wet. (Moisture forms, etc.)
5. It went down. (The car got cold.)
6. (Students will tell what they see.)
7. Particles of dust, etc.
8. A cloud (or fog) forms in the jar. (Some students may not be able to produce fog.)
9. We cooled it.
10. It added tiny particles of smoke.
11. (Students' data about room temperature or slightly below.)
12. It gets wet.
13. (Students' data. The temperature will rise several degrees.)
14. Heat went from the steam to the cup.
15. It became liquid.
16. The form of a gas.
17. The liquid form.
18. Changing the liquid to a gas (water vapor).
19. The land is warmer. Air moves from a cooler to a warmer region.
20. It is raining. As the cloud rose over the mountain it was carried up to a cold region where the water vapor condensed (became liquid).
21. Gravity.
22. You feel cooler.
23. The perspiration (sweat) uses up heat when it evaporates (turns to gas).
24. You might not lose enough water to keep you cool enough.
25. It was to provide something for the water vapor to condense on.
26. Students' answers. (Look for thought; no penalties if you disagree.)
27. Energy (heat).

**CONCEPT SUMMARY**: Water in the air is controlled by interaction with energy.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 4 (3 periods)

**PURPOSE**: Acquaint students with the way in which interacting matter and energy (heat and cold) wear away the surface of the earth.

**DEVELOPMENT**: Students will (A) fracture a bottle by freezing water in it, (B) gouge a board with sand and ice, (C) see swelling beans move a rock, (D) react a calcite rock with weak acid.

These activities will show students how energy interacts with matter to produce changes in the earth's surface.

**HIGHLIGHTS**: The water in the glass vial freezes and breaks the glass (No. 1, page 144).

Swelling beans break apart a piece of plaster (No. 14, page 145).

**LOOK AHEAD**: Start collecting one quart milk cartons for the next investigation.

**MATERIALS** (for each team of two)

*Part A–Freezing a bottle of water*
Jar, glass, with screw cap, 30 ml
Beaker, 400 ml glass or plastic
Salt, about 100 g
Ice, crushed, 6 or 7 ice cubes

*Part B–Gouging a board with sand and ice*
Wood, having smooth finish, 6" x 3" x 1" (these dimensions are not critical)
Sand, 3 g
Paper towel
Ice cube

*Part C–A bean seed moves a rock, bursts plaster*
Cylinder, graduated, 100 ml
Beans, dried (baby lima, pinto, etc.)–50 ml
Rock, to fit into the graduated cylinder
Ruler, 12" metric
Cups, paper, 1 oz.–2 are needed
Stick, wooden, to stir plaster
Plaster, patching, 70 ml

*Part D–Calcite reacts with lemon juice*
Calcite, $CaCO_3$, 10 g
Beaker, 100 ml
Lemon juice, 20 ml
Petri dish or 100 ml beaker

**Materials** (for the class)

*Part A*–Pan, etc. large enough so that students can close the lids of their bottles under water (stoppered sink will do)

**Preparation of Materials**

If crushed ice or an ice crusher is not available, wrap the ice in paper towels or cloth and pound with a hammer.

In part A, if the glass jar is filled with water that is near the freezing point, it will freeze much more rapidly.

Prepared lemon juice is more costly but less time consuming than using fresh lemon juice. The fresh juice may be more successful.

## TEACHING TIPS

**Responses to Expect:** Responses will depend upon the region you live in. Students who have grown up in areas with severe winters will not be surprised by the effects of ice. Those from warmer climates will show more reaction. Call on home freezer experiences; some students may have put a soda or something in a freezer and have had it burst.

During the discussion of the ice and sand, the boys may come up with files, rasps, and sandpaper. Keep the girl's morale up by leading them into naming nail files and emery boards.

**Practical Hints:** See if the preliminary remarks of the investigation arouse any speculation about the formation of the softer earth materials. Then get into the details of the procedure.

In part C, in order to save time and plaster, you may want to have some teams work only with the bean-plaster mixture, others only with the plaster, rather than having each team work with both.

If too much water is added to the plaster, it will be too soupy. Keep some extra powder on hand to thicken a watery batch. Be careful not to put plaster down the drain. The results could be catastrophic.

**Discussion and Review:** Parenthetically, you may arouse student interest by bringing up the subject of land use. The rising cost of food might be tied in part to the loss of arable land. Teenagers probably will react strongly to the suggestion that motor vehicles be banned as a means of recovering farm land.

Even though land use is an important issue, remember that the concept of the investigation is interacting matter and energy. Let the land use discussion continue as long as it is spontaneous, then come back to the concept.

Question 21 is really the summary: What is interacting to wear down the Earth's surface? Listen to student responses to be sure they have the point of the investigation.

## ENRICHMENT

1. Have a student repeat the bean experiment with cement instead of plaster.

2. Have a student improvise a method of measuring the force of expanding beans or other growing plants.

3. Find an example of plants pushing through pavement around the school where students may see it. Have them find it.

## REFERENCES

### Books


Bardach, John, *Downstream: A Natural History of the River.* New York: Grosset & Dunlap, Inc., 1966.

Paddock, William and Paul, *Famine–1975: America's Decision: Who Will Survive?* Boston: Little, Brown & Co., 1968.

U.S. Department of Agriculture, *Outdoors U.S.A.* U.S. Government, 1967.


### Multi-Media Aids

*Erosion:* 11 mm film, color, 10½ min., Bailey Cat. No. 16-252.

*Erosion–Leveling the Land:* 16 mm film, 14 min., EBF Color: Cat. No. 2194, B/W: Cat. No. 2195.

*Stream Table:* Film Loop Series, silent, color, 4 min., Wards:

| | Std 8 | Super 8 |
|---|---|---|
| a. *Mass Wasting: Dry:* | 74W1004 | 74W1024. |
| b. *Mass Wasting: Moist:* | 74W1005 | 74W1025. |
| c. *Stream Erosion Cycle:* | 74W1009 | 74W1029. |
| d. *Waterfalls:* | 74W1012 | 74W1032. |

*Water Erosion:* 8 or Super 8 film loop, silent, color, EBF Cat. No. 80110.

**POSSIBLE ANSWERS**

1. The water freezes. The bottle cracks open.
2. Yes. (Most groups.)
3. The ice will crack the rock.
4. Pieces of rock pile up at the bottom.
5. It is scratched (gouged, etc.) by the sand.
6. It is stuck in the ice.
7. A file, rasp, sandpaper, emery board, etc.
8. It causes rocks to be worn down.
9. (Student measurement.)
10. (The data will show a gradual rise. It will take a while to start; therefore, the first readings will be meager.)
11. It rose.
12. It might not rise as much. (Allow latitude here.)
13. It might split the rock.
14. (Student's descriptions.)
15. The beans split the plaster.
16. When the plant starts to grow.
17. Gritty.
18. Bubbles come off the solid.
19. It will be eaten away.
20. Energy. (Sunlight, heat from the sun, etc.)
21. Matter and energy.
22. It grows plants we need in order to live.

**CONCEPT SUMMARY**: Interacting matter and energy are wearing down the earth's surface.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 5 (2½-3 periods)

**PURPOSE**: Develop the concept that new materials are forming in the Earth's crust as a result of the interaction of matter and energy.

**DEVELOPMENT**: (A) Students will evaporate the water solvent from some blue dissolved crystals; (B) they will examine a rock specimen; and they will pour a water-gravel-sand mixture into a milk carton in order to observe the layering of the particles.

While students know that some of the specific changes in Nature are abrupt and violent (as demonstrated in the previous investigation), they will realize that the longer and broader view of Nature's changes reveals an underlying continuity.

**HIGHLIGHT**: The materials have formed layers in the carton (No. 9, page 150).

**MATERIALS** (for each team of two)

*Part A–Evaporating water from blue crystals*
Cylinder, graduated, 100 ml
Beaker, Pyrex, 100 ml
Beaker, Pyrex, 600 ml
Copper sulfate, blue crystals, ¼ teaspoon
Stirring rod
Ring stand
Ring
Wire gauze
Burner

*Part B–Layers of gravel in a milk carton*
Rock specimen, showing fossil impressions
Magnifying glass
Milk carton, 1 qt.
Pin, common, straight
Gravel, coarse, 100 ml
Gravel, fine, 100 ml
Sand, 100 ml
Pan, pie, aluminum, disposable, 7" diameter
(600 ml beaker and 100 ml graduated cylinder from part A)
Razor blade
Paper towels–about 3 are needed

**Preparation of Materials**

Sort out the materials for parts A and B. Have them in shoe boxes or whatever distribution system you use. The cartons and pie pans can be distributed together. The students will use the 600 ml beakers to mix their slurries of sand, clay, or gravel, and the pie pan to catch the runoff.

When it comes time to examine the rock specimens (part B), students will examine them less intently and with less interest if the rocks have been sitting around for some time. Therefore, pass them out as needed, not before.

Sand, clay, and gravel are not the only possibilities. Enterprising students who have done this as a take-home project used such unusual materials as cat litter and coffee grounds.

Cake cooler racks placed in plastic tote trays will make good drainage for the milk cartons. This protects the plumbing from sand and gravel. Or do the bulk of the draining in the sink, and let the draining be completed in the pie pans.

## TEACHING TIPS

**Practical Hints**: The groups can be studying the fossil specimens while their sand and solution mixtures have been set out to dry. The milk cartons should be stored in as warm a place as possible to facilitate drying of the sand-gravel mixture.

As is frequently the case when several activities take place in one investigation, instruction or discussion of the procedures should be broken up. Don't give instructions in one gulp at the beginning of the investigation; you will avoid repeating yourself and making students restless.

**Discussion and Review**: Stress that there is an interaction going on that requires energy at some stage. The theme is carried along throughout the investigation so there should be no surprise when it appears in the summary.

## ENRICHMENT

1. Have a student interested in auto racing report on the Bonneville Salt Flats.
2. Have a student devise a demonstration to show that as moving water slows down it is the heavier suspended particles that drop out of it first.

## REFERENCES

### Books

Bergaust, Erik, and William Foss, *Oceanographers in Action.* New York: G.P. Putnam's Sons, 1968.

### Multi-Media Aids

*Alluvial Fan and Lake Delta:* Super 8 loop, silent, color, 3 min., Ealing Cat. No. 85-0040/1.

*The Deep Frontier:* 16 mm film, color, 30 min., Modern 3009.

*Desalting the Seas:* 16 mm film, color, 17 min., A.E.C.

*Rocks that Form on the Earth's Surface:* 16 mm film, 16 min., EBF Color: Cat. No. 2198, B/W: Cat. No. 2199.

*Sedimentation:* 8 or Super 8 loop, silent, color, 3 1/2 min., EBF Cat. No. 80106.

*Sedimentation:* Super 8 loop, silent, color, 3¼ min., Ealing Cat. No. 85-0149/1.

*Sediment Deposition:* 8 or Super 8 loop, silent, color, 3 min., EBF Cat. No. 80743.

*Stream Table:* Film Loop Series, silent, color, 4 min., Wards:

| | Std 8 | Super 8 |
|---|---|---|
| *Sedimentation, Turbidity Currents:* | 74W1006 | 74W1027. |
| *Sedimentation, Settling Rate:* | 74W1007 | 74W1027. |

POSSIBLE ANSWERS

1. Students' answers. (It collects in low spots, in the ocean, etc.)
2. It evaporates (dries up, disappears, etc.).
3. The lake would dry up.
4. Colorless.
5. Blue crystals.
6. Students' answers. (A salty lake dried up, etc.)
7. Students' descriptions.
8. Students' answers. (There are remains of living things, fossils, in the rock. The rock had to be soft for living things to stick in them.)
9. Layers of sand, gravel, etc.
10. The bottom.
11. Level.
12. The bottom.
13. It may form layers.
14. Energy (heat).
15. Energy and bits of rock.
16. Energy (heat).
17. Energy.

**CONCEPT SUMMARY**: Matter and energy interact to form new layers on the earth.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 6 (2 periods)

**PURPOSE**: Discover the concept that matter and energy interact to form new materials.

**DEVELOPMENT**: (A) A dissolved solid will be recrystallized from a cooling solution; (B) phenyl salicylate will be melted and recrystallized from its cooling melt; (C) a "chemical garden" of nickel silicate crystals will be precipitated by mixing solutions of sodium silicate and nickel sulfate.

In each case the theme of interacting matter and energy is stressed, showing another example of this all-pervading idea.

**HIGHLIGHTS**: The potassium sulfate crystallizes out of solution (No. 2, page 152).

The phenyl salicylate crystallizes as it cools (No. 6, page 153).

The chemicals appear to grow in bizarre shapes (No. 11, page 154).

**MATERIALS** (for each team of two)

*Part A–Recrystallizing potassium sulfate from solution*
Cylinder, graduated, 100 ml
Beaker, Pyrex, 100 ml
Potassium sulfate, 10 g
Burner
Ring stand
Ring
Wire gauze
Stirring rod

*Part B–Melting and recrystallizing phenyl salicylate*
Test tube, Pyrex, 18 x 150 mm
Phenyl salicylate, 20 g
Beaker, plastic, 400 ml
(Ring stand, ring, and wire gauze of part A)

*Part C–Precipitating nickel silicate crystals*
Sodium silicate solution, 300 ml
Nickel sulfate, 18 g
Beaker, plastic 250 ml
Jar, wide mouth, peanut butter type, or 400 ml plastic beaker
Paper towel

**Preparation of Materials**

If you have solid sodium silicate, make up your solution of sodium silicate to a concentration of about 35 g of solid per liter of water. If you have the syrupy liquid type sodium silicate (known as "water glass"), dilute it with about 3 volumes of water.

Each bottle of chemicals should be set out with a separate spatula. Stand them on paper towels, far enough apart to discourage mixing.

If the room does not have piped hot water for part B, the students can heat it in a Pyrex beaker.

**TEACHING TIPS**

**Responses to Expect**: Some students may have had little kits to grow "Moon Rocks," "Magic Rocks," or chemical gardens. They will usually identify them by the name of the toy. This doesn't seem to take the edge off the activity for them.

**Practical Hints**: The materials for parts A and B and the instructions may be handled together. It will be more convenient to go over the procedure for C separately.

If the timing can be arranged, have the first observations of part C made at the end of the period; the solubility tests may be made the next day. Be sure the groups mark their containers with tape so they may be identified the next day.

If your students make their nickel silicate garden in a peanut butter jar they've brought in (rather than a beaker), they may want to take the jar and its contents home with them. If collecting jars is no problem, let them. You might get them to bring in a replacement. Those using beakers should clean them as usual. See that the solid material goes in the waste cans, not the drains.

**Discussion and Review**: Having used energy to change matter in two parts of the investigation, the continuing theme of interacting energy and matter is very visible to the students. When they can verbalize the last question, they have the concept of the investigation. In parts A and B, be sure that heat is seen as one form of energy.

## ENRICHMENT

1. Have one or more students demonstrate how to separate mixtures of floating and nonfloating materials by putting them into water. Wood chips and lead shot are convenient.

2. Have a student demonstrate how to separate a mixture of two solids, one water soluble, the other not.

3. Contact the public relations department of any local mining company for display materials, a speaker, or other aids.

## REFERENCES

### Books


Berry, James, *Exploring Crystals.* New York: The Macmillan Co., 1969.

Hurlbut, Cornelius S., *Minerals and Man.* New York: Random House, 1968.

Pearl, Richard M., *1001 Questions Answered About the Mineral Kingdom,* rev. ed. New York: Dodd, Mead & Co., 1968.

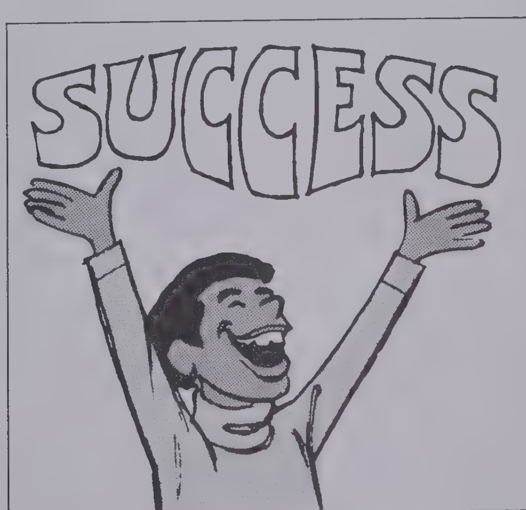

### Multi-Media Aids


*Chemical Changes in Rocks and Minerals:* Film strip, silent, color, Popular Science Publishing Cat. No. 4006.

*Limestone and Evaporites:* Film strip and record, color, EBF Cat. No. 6415.

*Rocks that Originate Underground:* 16 mm film, 23 min. E.B.F. Color Cat. No. 2402, B/W Cat. No. 2403.

*Volcanoes in Action:* 16 mm film, black and white, 11 min., E.B.F. Cat. No. 221.

POSSIBLE ANSWERS

1. The crystals dissolve.
2. Crystals form.
3. Heat (energy).
4. Loss of heat (energy).
5. The solid melts.
6. It hardens, (sets). It forms crystals.
7. Heat (energy).
8. Sodium, silicon, oxygen.
9. (Students' descriptions.)
10. Yes.
11. (Students' descriptions.)
12. Not very soluble. (They don't seem to dissolve, etc.)
13. No.
14. The properties have changed (are different).
15. They can turn back to a solid form.
16. The interaction of matter and energy.
17. The interaction of matter and energy.
18. Nickel sulfate and sodium silicate.
19. They melt and harden (cool or set). They crystallize from water. Materials interact to form new substances.

**CONCEPT SUMMARY**: Matter and energy interact to form new materials in the earth.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 7 (1½-2 periods)

**PURPOSE**: Relate the rise and fall of the Earth's surface to interactions of matter and energy.

**DEVELOPMENT**: (A) Students will observe rock, gathered from mountainous areas, that has marine fossils in it. (B) A floating board supporting ice will rise as the ice melts. (C) A cylinder placed on putty will sink as the putty rises around it.

(D) The conservation of natural resources will be considered.

**HIGHLIGHTS**: The wood rises as the ice melts (No. 7, page 157).

The weight gradually sinks through the soft surface (No. 14, page 157).

**LOOK AHEAD**: At the beginning of Investigation 7, students should start compiling information which will be used during Investigation 9. For part B of 9, record sunrise and sunset time for 1 week; for part C, measure the shadow of an upright pole for 7 consecutive days.

Don't explain the purpose of this information until Investigation 9 begins.

**MATERIALS** (for each team of two)

*Part A–Observing a rock*
Rock specimen with obvious marine fossils

*Part B–Floating board supporting ice*
Ice cubes–3 are needed
Wood, 2" x 2" x 1/8"
Beaker, 600 ml
Ruler, 12" metric
Paper towel

**MATERIALS** (for the class)

*Part C–Silly putty*
Cylinder, metal, a little less than an inch in diameter, about 2" long
Board, with hole filled with silly putty

**Preparation of Materials**

Making the board with the silly putty center: The board may have either a square or circular shape with a 3" edge or diameter. It should be about 1" thick. The hole bored in the center should be 1" in diameter 1/3 to 1/2" deep.

One way to make this piece of apparatus is to glue together two pieces of board, each of which is 1/2" thick but only one of which has a 1" diameter hole bored all the way through it.

The silicone putty should fill the hole flush with the top. A putty knife wider than the hole or a roller (brayer) may be used. A piece of wooden dowel would also work. The Welch catalogue lists a 2 ounce package (0704) of silly putty for about $4.00. Compare the cost and amounts of the packages in toy stores and discount houses, or contact a local chemical supply house for other sources.

The silly putty boards should be stored flat as the putty will slowly flow. They can be stacked as the contact surfaces are flat.

**TEACHING TIPS**

**Responses to Expect**: Students may not realize it's silicone putty, which may be good, as they will disarrange the surface less, and thus spare you the bother of having to smooth it over in preparation for the next class.

Fossils usually attract interest as students almost always show curiosity at seeing life forms embedded in rock. The length of time since these life forms were actually alive is not easily grasped by students, who tend to see 20 years as an eternity.

**Practical Hints:** Listen to student conjectures about why the earth is not smoothed off. It may tell you something either about how they think the earth is made or possibly about how little they consider what is under the pavement.

Keep an eye on the ice cube supply. As soon as all groups have what they need, quietly remove remaining cubes to prevent future problems.

See that the silicone putty doesn't stick to the weights when the students are through. Remember to smooth over the silicone putty or have the students themselves do it for the next class.

**Discussion and Review:** Bring in the need for energy to melt the ice and move things around. These are concepts that have been previously established. They can then be expanded to encompass earth movements.

In part D, discussion about vanishing resources should not be forced, but it is a relevant area of concern where science is very much involved.

## ENRICHMENT

1. Have a student do a long term experiment similar to part C, using a rock and a piece of "solid" tar.

2. Have one or more students do crystal growing, using sugar, Rochelle salts, or some other simple substance. It may be done as a demonstration or a contest for the largest, best formed crystal, etc. See that all participants get recognition if it is a contest.

3. Have a student demonstrate reducing ores to metals with a burner, lump of charcoal, and blowpipe.

4. Have a student find out and tell the class how much of the United States would be under water if the ice caps melted.

## REFERENCES

### Books

Carrington, Richard A., *Guide to Earth History.* New York: New American Library.

Clayton, Keith, *The Crust of the Earth: The Story of Geology.* Garden City, N.Y.: Natural History Press, 1967.

Park, Charles F., *Affluence in Jeopardy: Minerals and the Political Economy.* San Francisco: Freeman, Cooper, & Co., 1968.

### Multi-Media Aids

*Conquering the Sea:* 16 mm film, color, Modern Cat. No. 3013.

*Measuring Movements of the Earth's Crust:* Film strip with record, color, EBF Cat. No. 6414.

*Prehistoric Times: The World Before Man:* 16 mm film, color or black and white, 11 min., Coronet Cat. No. 717.

*Stream Table* Film Loop Series, silent, color, 4 min., Wards:

| | Std. 8 | Super 8 |
|---|---|---|
| *Type of Shorelines* | 74W1011 | 74W1031. |

*Structural Processes: Faults:* Super 8 loop, silent, color, 3 min., Ealing Cat. No. 85-0180/1.

*Vulcanism:* Super 8 loop, silent, color, 2¾ min., Ealing Cat. No. 85-0156/1.

*Why Do We Still Have Mountains:* 16 mm film, color, 11 min., Coronet.

**POSSIBLE ANSWERS**

1. The remains of living things (fossils) that came from the sea (dead sea life, etc.).
2. The rocks must have been under water.
3. Maybe the land rose (or the sea went down, dried up, pulled back, etc.).
4. Either the land was higher or the sea was shallower.
5. It's water level rose, making the oceans deeper.
6. It may have come up (students' answers, allow latitude).
7. It rose.
8. It rose.
9. It got deeper. (The water level rose.)
10. It might push it down.
11. Students' answers. (It would sink, squash down, etc.)
12. Students' measurements.
13. Students' measurements.
14. The metal is lower than when it started.
15. It rose (bulged up, was pushed up, etc.).
16. It sinks.
17. They may be pushed up.
18. It may be soft, and able to flow under pressure.
19. More silver was produced than used. (50,627 + 39,177 = 89,804 thousand ounces. 26,874 thousand ounces used.)
20. Less silver was produced than was used. (39,800 + 39,544 = 79,344 thousand ounces. 141,516 thousand ounces used.)
21. It's going down (running out).
22. Students' answers. (Try to steer the students toward conservation but it must come from them; no penalties if you don't agree with their answers but the answers should be honest, not flippant.)
23. Some parts are rising while others are sinking.
24. The interaction between matter and energy.

**CONCEPT SUMMARY:** Interacting matter and energy are raising and lowering the surface of the earth.

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## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 8 (2 periods)

**PURPOSE**: Show how the transfer of energy can carry information.

**DEVELOPMENT**: (A) Students will generate waves along a spring; (B) they will record the side-to-side motion of their hand on a piece of paper that is being pulled at a right angle to the motion of their hand.

The idea of sending information by energy waves is expanded to consider problems of nuclear test detection.

**HIGHLIGHT**: Transverse and compressional waves do not move at the same speed (No. 3, page 163).

**MATERIALS** (for each team of two)

*Part A*
Spring, Slinky

*Part B*
String, 1 meter long
Weight, 8 oz.
Paper, unlined—2 sheets are needed
Felt tipped pen (pencil will work, too)

**TEACHING TIPS**

**Responses to Expect**: Students will claim that rocks don't vibrate like springs. Reply by borrowing or improvising a stethoscope, and having a student listen on a concrete walk when someone taps it a few feet away with a piece of metal. Then ask him how the sound passed through the concrete.

**Practical Hints**: You may have to ask a few leading questions about sound and light to get the notion of waves out of the class.

Keep an eye on how the springs are handled. A high degree of judgment is necessary to decide when a student is engrossed with how an unfamiliar item of equipment works and when he is about to flip it at his neighbor.

Don't let students shake the springs too vigorously; otherwise they will soon become hopelessly tangled and bent out of shape.

Some students may note that the waves reflect from the end of the springs. If you show any film with seismographs, see if students can find an analogy between the reflections in the earth and the reflections in the springs.

**Discussion and Review**: The activity has demonstrated the waves and their uses. The summation section then ties down the notion of energy carrying information about the earth. This is your target.

In part C, have students' conflicting statements read aloud pro and con the Nuclear Test Ban. Remember that this is another case where the quality of the answer is more important than agreement with one side or another. You are neutral in a controversial question. If students insist on being told a "right" answer, ask if they are showing that 18-year-olds should vote.

**ENRICHMENT**

1. Have a student tie two or more springs together. He (or she) should point out the reflections at the spring junctions. These will be more pronounced if the springs are unlike in their masses and tensions.

2. Have a student build a seismograph with a heavy weight and a surplus clockwork mechanism. Let him show a record in class. He may pick up a quake or he may want to correlate results with heavy traffic conditions.

3. Have students bring in current newspaper articles on the pros and cons of nuclear testing.

## REFERENCES

### Books


Branley, Franklyn M., *The Earth: Planet Number Three.* New York: Thomas Y. Crowell Co., 1966.

Cervon, Jacqueline, *The Day the Earth Shook.* New York: Coward-McCann, Inc., 1969.

Earth Science Curriculum Project, *Investigating the Earth.* Boston: Houghton Mifflin Co., 1967. Pp. 350-356.

Henry, Bernard, *Earth.* New York: Roy Publishers, Inc., 1969.


### Multi-Media Aids


*Earthquake:* 16 mm film, color and black and white, 14 min., Bailey Film Associates Cat. No. 16-148.

*Earthquakes and Volcanoes:* 16 mm film, color and black and white, 14 min., Bailey Film Associates Cat. No. 16-19N.

*Exploring for Oil:* Filmstrip, silent, color, Heath 8A-6, 09159.

*The Hidden Earth:* 16 mm film, 27 min., McGraw-Hill, B/W: Cat. No. 681108, Color: Cat. No. 681121.

*The Interior of the Earth:* 16 mm film, 14 min., McGraw-Hill B/W: Cat. No. 653205, Color: Cat. No. 653305.

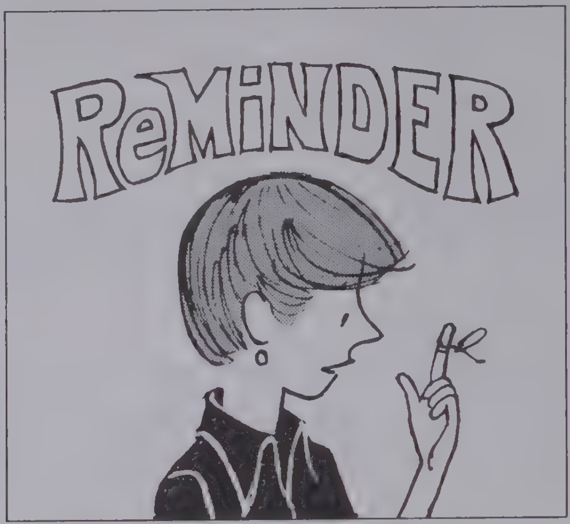
*What's Inside the Earth:* 16 mm film, color and black and white, 14 min., Bailey Film Associates Cat. No. 16-39.


## POSSIBLE ANSWERS

1. (Students' descriptions: The bump moves down the spring.)
2. (Students' descriptions: The squeezed spot moves down the spring.)
3. (Students' data. Compression wave moves faster, but the difference is difficult to detect.)
4. One a short time before the other.
5. The time between receiving waves will be greater.
6. It moves from side to side with the same speed you move your hand.
7. Doesn't move as far from side to side.
8. It would move from side to side, the amount depending on how fast the floor moves.
9. There is a wavy line.
10. The waves are closer together.
11. 4 minutes, 52 seconds.
12. A little after 1:58 A.M. (22 seconds after 1:58 A.M.)
13. Students' answers. (About 8½ to 9 minutes from the graph. The precise measurement is 8 min., 42 sec.)
14. Students' answers. (About 4,500 miles from the table. Student will have too much trouble interpolating on this table very closely. The precise measurement was 4,625 miles.)
15. Students' answers. (Look for a well supported answer.)
16. Energy.
17. Energy waves (waves of energy, etc.)

**CONCEPT SUMMARY**: Energy waves carry information about the earth.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 9 (4-5 periods, partially concurrent with Inv. 7 and 8)




You started recording sunrise and sunset, and measuring the shadow during Investigation 7. Use that information now.

**PURPOSE**: Acquaint students with the seasonal change in the amount of energy reaching the Earth from the sun.

**DEVELOPMENT**: The practical importance of this is discussed in terms of the monthly fuel bill.

**HIGHLIGHTS**: The days do show a regular change in length (No. 6, page 168).

The length of a shadow changes from day to day (No. 10, page 169).

**MATERIALS** (per team of two students)

*Part C–The length of a shadow*
Dowel, 2 feet x ½" mounted vertically in a portable base.
Meter stick

**Preparation of Materials**

Take some preliminary measurements in advance of the class, to have an idea of what they will get. This will help spot students who are having trouble. Don't tell them how wrong they are, but review their procedure until they see its flaws.

**TEACHING TIPS**

**Responses to Expect**: Student responses will probably range from, "I knew it all along" to "Oh." Most of the population is aware of the changing daylight hours in terms of how much daylight is left when they get home from work or school. Some of the more thoughtful students may be struck by the symmetry of the curve when they plot the monthly changes.

**Practical Hints**: In part A, be prepared to help students with arithmetic on finding the gas bill.

In part C, finding the change in the angle of the sun's rays over a 7-day period, the length of the upright's shadow will change perceptibly over the course of a minute. Therefore, it is better to have students first mark the tip of the shadow at the critical moment so that they can then leisurely and carefully measure its length. A nail will mark the ground, chalk the pavement.

Alternatively, you won't have to go outdoors if the sun hits your classroom windows. Simply block one window with an opaque material having a hole in it. Then mark the spot of light each day with a series of markers that may be left in place over the seven-day period.

If a weekend intervenes during the shadow measurements, it will not hurt. The daily change may be masked by measurement errors so the extra time will be an advantage. This is not a problem with sunrise and sunset numbers, as these can usually be found in newspapers in the library.

If students have trouble subtracting times, in part D, try explaining the 24-hour clock. They add 12 to all the p.m. times before subtracting.

Some students will still make heavy weather of the graphing. They have problems placing units on the axes with proper spacing and in connecting points to make a smooth curve.

**Discussion and Review:** Keep in mind the main theme: The amount of energy reaching the earth is seasonal. After battering away at this theme with gas bills, weather maps, and so on, the concept should be well established by the time a summary is called for.

## ENRICHMENT

1. Have a student keep a shadow record during the week centering around Dec. 21 to show the change after the winter solstice.

2. Challenge an appropriate student to decide why winter starts with the shortest day instead of being centered around it. (You may have to explain the time lag in terms of a pot cooling off for a while after the fire is out.) The same question can be asked about summer starting on the longest day.

WARNING: BE SURE TO EMPHASIZE THE DANGER OF LOOKING AT THE SUN FOR EVEN THE BRIEFEST TIME. THIS IS NOT APPRECIATED BY THE GENERAL PUBLIC AND THERE ARE REPORTS OF PERMANENT EYE DAMAGE AFTER EVERY ECLIPSE.

## REFERENCES

### Books

Adler, Irving, *The Sun and Its Family.* New York: Signet Science Library (New American Library), 1958.
Cartright, Edgar M., ed., *Exploring Space with a Camera.* U.S. Government, 1968.
Ellison, M.A., *The Sun and Its Influence,* 3rd ed. New York: American Elsevier Pub. Co., Inc., 1968.
King, Henry C., *The World of the Moon.* New York: Thomas Y. Crowell Co., 1966.
Knight, David C. *The First Book of the Sun.* New York: Franklin Watts, Inc., 1968.

**Multi-Media Aids**

*How We Study the Sun:* 16 mm film, color, 14½ min., Bailey Film Associates Cat. No. 16-622.

*Lunar Eclipses:* Super 8 loop, silent, color, 3 1/2 min., EBF Cat. No. 81150.

*The Nearest Star:* 16 mm film, sound, 27 min., McGraw-Hill B/W: Cat. No. 681105, Color: Cat. No. 68118.

*Solar Eclipse:* Super 8 loop, silent, color, 3 min., EBF Cat. No. 81149.

*The Sun:* 16 mm film, sound, black and white, 29 min., N.E.T.

*To the Moon:* 16 mm film, color, 30 min., Modern Cat. No. 3002.

**POSSIBLE ANSWERS**

1. December.
2. August.
3. $7.28. ($9.42–$2.14.)
4. It's not needed in the warm weather.
5. Cooler. There is less time for the land and air to heat up.
6. Students' data. (Shows gradually changing day length: shortening in the fall, lengthening after Christmas vacation until summer.)
7. (Warmer if days are lengthening, cooler if days are shortening.)
8. It's shorter.
9. Students' predictions. (Most students will probably say *different* or *shorter.*)
10. (Data shows slight change day to day.)
11. (The answer will depend upon the data. The sun will be higher if the shadow grows shorter.)
12. (The answer will depend upon the data. Expect warmer weather if the sun is getting higher and vice versa.)
13. December.
14. June.
15. 32°F.
16. About a fourth.
17. Northern United States.
18. Hot, over 100°F.
19. The Mexican border.
20. In June.
21. In June and July looks like a hilltop. It drops down to low levels during January and December.
22. Shortest hours of daylight during December and January; longest during June and July; intermediate hours of daylight between these two extremes.

**CONCEPT SUMMARY**: The amount of energy reaching Earth changes regularly with time.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 10 (2-2½ periods)

**PURPOSE**: Find that the energy received from objects in space may be used to locate them.

**DEVELOPMENT**: (A) Students will use a range finder they construct and calibrate themselves. (B) They will estimate distances using a method based on parallax.

(C) These methods of measuring interplanetary distances will lead into a discussion of cost priorities, as these are related to the space program.

**HIGHLIGHT**: When the observer changes positions, objects in the foreground seem to move much more than objects some distance away (No. 14, page 175).

**MATERIALS** (for each team of two)

*Part A – The range finder*
Paper, unruled, 8½ x 11–4 pieces are needed
Paper clips, standard size–4 are needed
Tape, masking, 4 foot length
Dowel, wooden, 2 feet x ½", mounted upright in a portable base
Ruler, 12" metric
Meter stick

**MATERIALS** (for the class)

*Part B–Distance by parallax*
Length of wrapping or butcher paper equal to the width of the room. Heavy black lines are ruled across at one meter intervals. The lines are numbered consecutively. With rooms under 25 feet wide, make the line spacing one-half meter.
Four sticks, about 5 feet long, mounted vertically on bases, labeled A, B, C, and D.

**TEACHING TIPS**

**Responses to Expect**: Expect questions about eyes and distance vision. For interested students, try the enrichment activity.

To work up more response to the parallax section (part B), try using stars on the back wall with numbers on them instead of lines. This should work up some interest when the students enter the room.

**Practical Hints**: In part A, the reason for taping paper together to make the range finder is to make a piece that will be wide enough to give accurate measurements. It should fit flat on the desk with no part hanging over an edge, so that you may have to use smaller paper if your desks are small.

Instruct students to tape the paper clips into the three corners securely, so that they don't move.

Have students sight along the top of the vertical pieces of the paper clips. To avoid crowding, you may want to have some teams working along the length of the room while others work along the width.

In part B, have the positions of the markers and the observation points marked on the floor with masking tape. This will allow the equipment to be cleared for another class, then set out again in a matter of seconds.

When going over the beginning of part A, don't be a spoil sport about a burst of eye crossing. It will die down shortly and you won't have to squelch any enthusiasm. There will be another burst of eye action with part B. The same conditions apply.

When choosing the sighting points, R and L, be sure that the targets are visible against the numbered background. Spend a moment to see what data the students will find. This will allow you to catch gross errors before discussion.

As there will be some traffic problems with the whole class trying to make parallax readings at once, try dividing the class so that one part does the range finder activity while the other is trooping across the front of the room.

**Discussion and Review:** In showing the measurement techniques, don't lose sight of the fact that energy from distant points allows us to locate them. The techniques are useful but not an end in themselves. This should be reinforced as the investigation draws to a close.

If a spirited discussion develops on the cost and utility of the space program, keep it going as long as it is not forced. Remember you are neutral and are just presenting data. The decisions are the students' and you are looking for decisions based on data, not agreement with a particular side.

## ENRICHMENT

1. Have one or more students try estimating distances with one eye covered. Let them throw balls or darts at a target while wearing an eye patch.

2. Enlarge the space program question into a debate between two sides. Have the class establish criteria to judge the debate.

3. Have a student demonstrate, with a mirror or prism, how a camera range finder works.

## REFERENCES

### Books

Asimov, Isaac, *Twentieth Century Discovery.* Garden City, N.Y.: Doubleday & Co., Inc., 1969.

Clarke, Arthur C., *The Promise of Space.* New York: Harper and Row, 1968.

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Gatland, Kenneth, *The Pocket Encyclopedia of Spaceflight: Manned Spacecraft.* New York: The Macmillan Co., 1967.

Halacy, D.S., *Colonization of the Moon.* Princeton, N.J.: D. Van Nostrand Co., 1969.

Holmes, David C., *The Search for Life on Other Worlds.* New York: Sterling Publishing Co., Inc., 1966.

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Von Braun, Werner, and Frederick I. Ordway, *History of Rocketry and Space Travel.* New York: Thomas Y. Crowell Co., 1967.

### Multi-Media Aids

*Mars and Beyond:* 16mm film, 30 min., color, Modern Cat. No. 3006.

*Measuring in Astronomy: How Big, How Far:* 16mm film, color, 11½ min., Bailey Film Assoc. Cat. No. 16-289.

*Scientific Measurement–Molecules to Stars:* Filmstrip, silent, color, Popular Science Publishing Cat. No. 588.

*Space Science: Man-Made Satellites:* 16 mm film, color or black and white, 11 min., Coronet Cat. No. 1648.

*Why Explore Space:* 16 mm film, color or black and white, 19 min., Churchill.

**POSSIBLE ANSWERS**

1. Less cross-eyed.
2. Students' measurements.
3. Students' calculations.
4. Students' opinions.
5. Students' measurements.
6. Students' calculations.
7. Students' opinions.
8. Make the width AD greater; make it from more rigid materials than paper; etc.
9. To measure the width of a river, the distance from the ground to an airplane, from Earth to moon, etc. To measure distances over rough terrain, to make a quick measurement of distance (assuming you have at your disposal an instrument that has already been calibrated).
10. It seems to move.
11. Less.
12. Nothing is moving. (The background and foreground *appear* to move relative to each other.)
13. Students' data.
14. Students' data.
15. On the horizontal axis find the observed parallax for the target. Follow this straight up to the point above it on the curve. From this point go straight over to the other axis where the target distance will be given.
16. Very, very great (too great to line the target up with an object in the background).
17. Education: 377 million dollars.
18. Space research and technology: 5,300 million dollars.
19. 72 times (72 x 74 = 5,328).
20. Students' answers. (You'll have a more lively discussion if you refrain from asserting your own opinion, and let students argue it among themselves.)
21. Energy.

**CONCEPT SUMMARY**: Light energy from objects is used to locate them.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 11 (1½-2 periods)

**PURPOSE**: Show how the energy radiated by stars is used to analyze them.

**DEVELOPMENT**: (A) The ability to obtain information from light will be shown by observing color changes caused by increased temperature. (B) The spectra of different gases will be observed with a simple grating.

The spectral similarities of terrestrial and nonterrestrial matter will be used to suggest a universe made up of the same elements that occur on Earth.

**HIGHLIGHTS**: As wire is heated, its color changes from red to yellow (No. 2, page 180).

Different elements produce different spectra (No. 14, page 182).

**MATERIALS** (for each team of two)

*Part A–Heating substances to incandescence*
Rod, carbon, 1/8 inch dia., about 3" long
Wire, copper, 1/16 inch dia., about 3" long
Wire, steel, 1/16 inch dia., about 3" long
Cork, small (handle to hold the heated wires)
Burner
Wire gauze (to put heated materials on)

*Part B–Spectra*
Flashlight, common (to hold two 'D' cells)
Paper, black, about 3 inches square
Tape, masking, 4 or 5 inches
Paper, white, 8½ x 11
Prism
Grating, diffraction transmission

**MATERIALS** (for the class)

*Part B–Spectra*
Power supply for the spectrum tubes
Gas spectrum tubes: hydrogen, neon, helium, argon, etc. (at least two)
Ring stand
Clamp, burette–as many as you have spectrum tubes.

**TEACHING TIPS**

**Responses to Expect**: The heated wire does not elicit much response but the gratings usually do, especially when they pick up spectra from all light sources. Some students may be able to tie the results with the prism to rainbows. Expect to take a few minutes to let the class play with the gratings before getting down to business.

**Practical Hints**: See that the nail and other specimens are heated hot enough to show the color shift from red to yellow. The usual lab burners won't give enough heat for a white or blue-white effect.

The greatest problem with the gratings is to get students to look to one side of the light source. It is also necessary to see that the rulings are parallel to the source. Have the students follow your hand with their eyes as you move it horizontally away from the light until they begin picking up the spectrum. After the first time it isn't much of a problem.

Students may want to try the prisms on the various gas tubes. Let them. Usually prisms are used with lenses to produce sharply defined spectra. This will be mentioned in enrichment as an additional activity.

**Discussion and Review**: The idea of energy conveying information was introduced in the last investigation. Here we are expanding on the theme by having energy tell about the composition of the light source instead of merely locating it.

We do not go into too many details of spectroscopy. We do, though, contrast the continuous spectrum of a hot solid and the line spectrum of an incandescent gas. But the fact that our sun gives a continuous spectrum while the outer atmospheres of the stars give line spectra is too complex for this course. This also applies to other phases of spectroscopy such as the infrared work of organic chemists. It's not for general student consumption, but don't discourage an interested student if he wants to probe further. He may get hooked on science.

**ENRICHMENT**

1. Have a student demonstrate spectra produced with a prism and lenses.

2. Have students make a display of spectra of different elements.

3. Have students observe through the gratings different light sources such as mercury vapor lamps, sodium vapor street lights, and fluorescent tubes. See if they can see the same mercury spectra lines in the fluorescent tubes that are present in the street lights.

**REFERENCES**

**Books**


Adler, Irving, *The Stars.* New York: John Day Co., 1956.

Asimov, Isaac, *To the Ends of the Universe.* New York: Walker & Co., 1967.


**Multi-Media Aids**

*Fingerprints of the Stars:* 16mm film, color, 12 min., Bailey Film Associates.

*Light and Color:* 16mm film, color, 14 min., EBF Cat. No. 1876.

*Space Science: Studying the Stars:* 16 mm film, color or black and white, 13½ min., Coronet Cat. No. 1644.

*Sound Waves and Stars:* 16mm film, color, 12 min., Bailey Film Associates Cat. No. 16-104.

**POSSIBLE ANSWERS**

1. Dark red.
2. It gets yellower (orange, lighter).
3. It makes the wire yellower (lighter, brighter) as it gets hotter.
4. First it is red, then orange (or yellow).
5. The same thing happens.
6. Simply how hot it gets.
7. (From the experimental evidence the students have, they will most likely say *yellow.* If the burner were able to heat the wire hotter, it would develop a bluish cast.)
8. White.
9. A rainbow (band of color.)
10. Different colors.
11. A rainbow (band of colors, goes from red to blue, etc.)
12. A set of colored lines. (Colors depend upon the element used.)
13. (Data given in class.)
14. (A description of spectra of different gases used.)
15. They are all different.
16. By looking at it through a grating to see what color lines it gave.
17. The spectrum of the flashlight was like a rainbow; that of the gas tubes had lines of different colors.
18. The same.
19. Students' answers.
20. Light energy from stars travelled through space.

**CONCEPT SUMMARY**: We learn what stars are made from by the energy they send us.

## PHYSICAL SCIENCE IDEA 4: INTERACTION, Investigation 12 (1½-2 periods)

**PURPOSE**: Develop an understanding of the mechanism that produces the varying energy of the seasons.

**DEVELOPMENT**: (A) & (B) Students will manipulate models of the Earth and sun to see how the energy reaching different parts of the Earth varies with time.

The Earth's rhythmic ballet around the sun is interpreted as the cause of the seasons.

**HIGHLIGHT**: The point near the pole gets more light when the pole is tipped toward the sun but less when it tips away (Nos. 3 and 4, page 184).

**MATERIALS** (for each team of two)

*Parts A and B–the rotating Earth*
Ball, 3 inch diameter with ½" hole through the center (styrofoam sphere is suitable)
Dowel, 7" x ½" (axis for sphere)
Wood base with holes to support dowel and sphere
Socket with 6 feet of cord and plug
Bulb, 40 watts or less
Ring stand
Clamp, burette
Protractor

**Preparation of Materials**

The sphere should have marked upon it the Equator and one line running from pole to pole. Mark every 10 degrees from pole to pole. The dowel should protrude a short distance through the sphere. The sphere should rotate against moderate friction. The dowel should mount on the base in two positions, vertical and inclined 23½ degrees from vertical.

**TEACHING TIPS**

**Responses to Expect**: This will depend upon latitude. The farther north students live the more aware they have become of the changes in daylight hours. This may be confused with the daylight saving shifts at the end of April and October.

Some students may be surprised to find that polar regions do not have exactly six months of light and six months of darkness.

**Practical Hints**: See that the lights on different tables are staggered so that conflicting shadows are eliminated. Darken the room as much as possible. Caution students about hot light bulbs. Bulbs 40 watts or less are not a severe hazard. They also are not as glaring as the larger sizes.

Use a regular globe to establish that larger latitude angles mean locations farther north. Ask about the Canadian cities that have lower latitudes than some U.S. cities. The southern swing of the border in the Great Lakes area comes as a surprise.

It may take some help to orient students to see themselves standing on a ball looking toward the light. Even though we know we are on a globe spinning through space, responses tend to be geocentric.

Seeing ourselves on "Spaceship Earth" takes practice. A cartoon transparency of a figure viewing the sun from his sphere will help put this idea over. Or you may prefer dolls or models.

**Discussion and Review**: To stimulate discussion show, with either chalkboard or projector, a position of the Earth relative to the sun. Ask what season it is. Use this as the opener to establish that the moving Earth is the cause of seasonal changes in energy. This can lead into the concept summary.

The final summation of the whole Idea can follow either at this point or when the set of sheets are returned. The concepts can be reviewed by having a student read them aloud. The recurring theme of interacting energy and matter will establish the changing nature of our environment.

## ENRICHMENT

1. Have a student describe what Earth seasons would be like if the poles were tipped either more or less than they are now.

2. Have a student explain why we have not considered changes in the distance between the Earth and the sun in talking about seasons.

3. Have a student explain the differences in the climates of parts of Labrador and Europe, which are at the same latitudes. Naturally he will have to learn about the Gulf Stream for an explanation.

4. Have a student use a pendulum to show that the Earth moves.

## REFERENCES

### Books


Ley, Willy, *Inside the Orbit of the Earth.* New York: McGraw-Hill Book Co., 1968.


### Multi-Media Aids

*The Earth:* Transparencies, color, Popular Science Publishing Set. TEV-1.

*The Earth in Space:* 16mm film, black and white, 29 min., N.E.T.

*The Earth's Movements:* 16mm film, black and white, 11 min., EBF Cat. No. 18102.

*How We Know the Earth Moves:* 16mm film, color or black and white, 11 min., Bailey Film Associates Cat. No. 16-43.

*Latitude, Longitude, and Time Zones:* 16mm film, 25 min., N.A.S.A.

*Solar Eclipse Expedition 1966:* 16mm film, color, 32 min., A.E.C.

*Why Seasons Change:* 16mm film, color or black and white, 11 min., Bailey Film Associates.

## POSSIBLE ANSWERS

1. The earth is rotating.
2. The same length of time.
3. The point near the North Pole.
4. The point on the Equator.
5. They would all be the same.
6. (Find answer in tables.)
7. The first position gave the longest day; the third position the shortest; positions 2 and 4 were intermediate in length.
8. One year.
9. Position 1.
10. Summer.
11. All the time.
12. Position 3.
13. Winter.
14. None of the time.
15. It tips its axis at the North Pole away from the sun.
16. Rotates about the sun.
17. Travels around the sun.

**CONCEPT SUMMARY:** The movements of Earth affect how much energy that parts of it receive. This causes the seasons.

**IDEA SUMMARY:** Matter and energy are constantly interacting, producing our changing environment.

# Idea 5
## Technology

Idea 5 is the concluding idea of IIS. It comes closest to the world students know best as it considers familiar objects like the telephone, plastics, and nail polish. Here students will discover that:

MAN'S UNDERSTANDING OF THE INTERACTIONS OF MATTER AND ENERGY ALLOWS HIM TO CONTROL HIS ENVIRONMENT.

Eleven investigations are used to develop the Idea. The first two establish the control of energy. The next shows the man-made nature of much of our everyday environment through the preparation of commonplace materials. The next three investigations look at electricity as the form of energy we depend upon most for the functioning of our mechanical surroundings. One investigation looks at transportation, three others at communication. The last considers safety and survival in our man-made world.

## PHYSICAL SCIENCE: IDEA FIVE (TECHNOLOGY)

### Man's Understanding of the Interactions of Matter and Energy Allows Him to Control His Environment

| *INVESTIGATION* | *CONCEPT DEVELOPED* | *NATURE OF THE ACTIVITY* |
|---|---|---|
| 1. YOU TURN ME ON | Switches let us control energy. | Operating simple switches and thermostats |
| 2. BLOCK THAT BREEZE | We use matter to control the energy around us. | Insulating ice with paper; testing samples for thermal and electrical conduction |
| 3. I MADE IT MYSELF | We are surrounded by a man-made environment. | Mixing concrete; making a urea-formaldehyde synthetic which will glue wood |
| 4. THE FORCE TO MOVE MOUNTAINS | Useful work may be done when energy changes form. | Changing electrical energy to light, heat, and magnetism; making electricity with electrodes in salt solution and detecting it with an ammeter |
| 5. IT'S DONE WITH WIRES | Magnetic energy may be converted to electrical energy. | Producing electricity by poking magnet and electromagnet inside a coil; blowing a 0.2 amp fuse |
| 6. MOTORS TURN YOU ON | Interacting electricity and magnetism can do work. | Producing turning-forces by magnets and electromagnets; assembling and operating electric motor |
| 7. YOU GET IT HERE AND LEAVE IT THERE | Transportation depends upon interacting matter and energy. | Investigating aerodynamics with paper strips and Ping Pong ball; studying inertia |
| 8. MAKING THE BIG SOUND | Interacting electricity and magnetism can produce sound. | Assembling telegraph and speaker; investigating an earphone |
| 9. SORRY, WRONG NUMBER | Sound may be converted to patterns of electrical resistance, making speech over long distances possible with wires. | Vibrating rulers and rubber bands; changing the current by changing the resistance; assembling microphone and using it with earphone |
| 10. IT'S NOT FOR REAL | Understanding magnetic waves lets us send pictures through space. | Inspecting movie film; showing animation by flip-pictures; showing illusion of motion by string of lights; analyzing and reconstructing optical image |
| 11. YOU HAVE TO STAY SHARP | An understanding of technological uses of matter and energy is needed to be safe in our man-made world. | Producing chlorine from household chemicals; burning nail polish, remover, and absorbent cotton; comparing the slipping ease of rubber-backed and plain carpets |

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 1 (1½-2 periods)

**PURPOSE:** Develop the concept that man has devised ways to control energy.

**DEVELOPMENT:** (A) Students will operate a simple electric switch. They will observe the action of (B) a simple thermostat and (C) an automobile thermostat.

Students will see that switches are a common means for controlling energy.

**HIGHLIGHTS:** Breathing on a thermostat turns off the light (No. 4, page 189).

Heating an automobile thermostat opens it up (No. 9, page 190).

**MATERIALS** (for each team of two)

*Part A–Electric switch*
Battery pack, 4 flashlight D cells
Bulb, flashlight
Socket for flashlight bulb
Wires, clip leads–3 are needed
Switch, knife, simple

**MATERIALS** (for the class)

*Part B–Thermostat demonstration*
Switch, thermostatic, 85° to 100° Celsius range
(Equipment listed under part A above)

*Part C–Automobile thermostat demonstration*
Thermostat, automobile radiator
Beaker, Pyrex, 600 ml
Burner
Ring stand
Ring
Wire gauze
Thermometer, standard laboratory

**Preparation of Materials**

Automobile thermostats can be obtained from local auto wreckers. It is usually advisable to put them in water and heat to boiling to be sure they operate. Clean them up a bit by putting detergent in the water.

Electric leads consist of about a foot or so of stranded insulated wire with an alligator clip on each end. Stranded wire is preferable since solid wire is not sufficiently flexible.

**TEACHING TIPS**

**Responses to Expect:** Some students will count how many switches they used before coming to school. Some students may vie for the largest number, others for the smallest.

There will be more interest among boys than girls for the car thermostat. Cater to the girls by getting a thermostat from an iron used for pressing clothes. Try a local repair shop.

**Practical Hints:** Auto thermostats may be set at different ranges depending upon operating conditions. Generally they open pretty close to boiling. Find some fish tank thermostats to exhibit or demonstrate.

The idea that turning on a toaster or a hi-fi is controlling energy may be novel. The switch on a car controls several hundred horses. This is one opening wedge for discussing control.

**Discussion and Review:** The point we are pushing for is that man controls energy. Switches are a dramatic way to introduce the concept. Controlling energy and its interactions with matter is a distinguishing feature of a technological society and it is the theme of this Idea.

Don't spend too much time on the overall picture of matter and energy. If it is made too important at the beginning, the final idea of this unit will seem too anticlimactic.

**ENRICHMENT**

1. Have a student demonstrate the use of fish tank thermostats. Use light bulbs to show when the circuits are on or off.

2. Have one or more students make a survey of different control switches and valves used at home, or in school, gas station, or shop of some kind.

3. Have one or more students look into how many switches they use now compared to the number their parents or grandparents used as teen-agers.

**REFERENCES**

**Book**

Allen, William A., *Know Your Car.* Chicago: American Technical Society, 1960. P. 42, pp. 44-45.

**Multi-Media Aids**

*Automation: What It Is and What It Does:* 16mm film, color or black and white, 13½ min., Coronet Films Cat. No. 1661.

*The Control Revolution:* 16mm film, black and white, 29 min., Indiana University.

**POSSIBLE ANSWERS**

1. Take off a connection (unhook a wire, etc.).
2. It lets you turn things on and off more easily.
3. Switches are safer; switches make it easier; etc.
4. The light goes out (the contacts move apart).
5. The light goes on (the contacts come together).
6. Energy (heat).
7. A thermostat.
8. The spring must be pushed against.
9. It moves (a ring opens, a hole opens, etc.)
10. Students' data. (From about 85°C to boiling.)
11. It keeps the engine temperature constant.
12. Energy (heat).
13. Energy (electricity, temperature, etc.).
14. They interact with energy.

**CONCEPT SUMMARY:** Switches let us control energy.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 2 (1½-2 periods)

**PURPOSE:** Demonstrate that man uses materials of various properties in order to variously control energy.

**DEVELOPMENT:** (A) Students will use paper toweling to insulate an ice cube. (B) They will successively hold on to one end of copper, iron, carbon, and glass rods while heating the other end. (C) They will observe the radiation of heat from a light bulb. And (D) they will put the rods of (B) in series with a battery and a flashlight bulb.

Students will realize that energy control has a prominent place in the everyday world of clothes, sunglasses, and TV, as well as in the world of science and technology.

**HIGHLIGHTS:** The paper-wrapped ice loses less weight than the unwrapped ice (No. 1, page 191).

The materials that won't conduct heat also won't conduct electricity (No. 25, page 194).

**MATERIALS** (for each team of two)

*Part A–Ice cube wrapped in a paper towel*
Ice cubes–2 are needed
Paper towels–about 4 are needed
Balance, platform

*Part B–Heat conduction of various materials*
Burner
Wire Gauze (to lay heated rods on)
Rod, copper, about 1/8" in diameter and 4" long
Rod, iron, same size
Rod, glass, same size
Rod, carbon, same size

*Part D–Electrical conduction of various materials*
(Rods of part B)
Battery pack, 4 flashlight D cells
Bulb, flashlight
Socket, flashlight
Wires, clip leads–3 are needed

**MATERIALS** (for the class)

*Part C–Radiation of heat*
Socket, with 6 foot cord and plug–4 per class are needed
Bulb, 40 watt–4 per class are needed

**TEACHING TIPS**

**Responses to Expect:** Students of this generation will not be familiar with the old trick of wrapping ice in newspaper to make it last longer.

Some students may wonder if the number of batteries makes a difference in how well some of the samples conduct electricity. Let them try it. But prolonged contact at higher voltages will burn the bulbs out.

Students may have stories of shocks or short circuits. Use them in context to illustrate electrical safety.

**Practical Hints:** Have available for students to inspect some different types of insulating materials such as fiber glass, rock wool, and asbestos. Also have available different kinds of wire covered with plastic, rubber, asbestos, or cotton covering. Whatever other samples of insulation can be scrounged from local building supply distributors are also appropriate.

You might want to try a demonstration used by home insulation salesmen. To do it, you place a penny on top of some insulation that is resting on your hand, and then, while still holding it, use a torch of some kind to melt the penny. This is dramatic, but you should try it cautiously beforehand so that you know exactly what you are doing.

**Discussion and Review:** The theme of the first investigation is carried into this one. We can stop or start the action of heat or electricity at will by the way we make use of the various properties of matter. The fact that a piece of asbestos or a plastic coating stops heat or electricity is an example of control.

**ENRICHMENT**

1. Have a student demonstrate the change in the electrical properties of glass with heating. This requires safety supervision. A piece of soft glass rod or tubing is placed in series with a regular light bulb and connected to the regular outlet. The glass rod is supported over a burner. As the glass is heated close to melting, its resistance decreases due to ion migration and the bulb lights. The glass should be over asbestos, as the current flow heats it to melting that finally breaks the circuit.

2. Have a student test thermos bottles by putting boiling water in one or more, and ice water in others. Have temperatures taken after 24 hours to show how effective the bottles were. Use other materials, such as layers of newspaper, for comparison.

**REFERENCES**

**Multi-Media Aids**

*Learning about Heat:* 16 mm film, black and white, 8 min., EBF Cat. No. 889.

**POSSIBLE ANSWERS**

1. The unwrapped cube.
2. Energy (heat).
3. It kept the heat out.
4. It keeps heat out.
5. It gets hot.
6. The glass rod doesn't get hot over its entire length.
7. It acts more like the copper. It gets hot.
8. It acts more like the glass (but it doesn't melt).
9. Copper, iron, carbon, glass. (Hopefully.)
10. Heat from the water can pass through copper easily.
11. It keeps the heat in (heat won't pass through it very fast).
12. They would carry heat away too fast (cool the glass too fast).
13. Copper. It carries heat the best.
14. A nonconductor (insulator).
15. Heat.
16. Not as much heat.
17. They stop (absorb) some of it.
18. The bulb lights.
19. The light glows with iron; it may glow feebly with carbon if the contacts are close enough. It will not glow with glass.
20. It carries or conducts electricity.
21. The glass won't conduct electricity.
22. Glass supports keep the electricity in the wire.
23. Copper.
24. It keeps people from being shocked. (Killed, etc., so you won't touch electricity and another conductor at the same time. It keeps the electricity in, prevents shorts, etc.)
25. Copper carries both heat and electricity well; glass carries neither well.
26. Materials that carry heat well will carry electricity well too.
27. It holds it in (blocking it from the table).
28. It holds energy in.

**CONCEPT SUMMARY:** We use various materials to control the energy around us.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 3 (2½-3 periods)

**PURPOSE**: Develop the concept that much of the modern environment is man-made.

**DEVELOPMENT**: (A) Students will make some cement. (B) They will glue together two pieces of wood, using a urea-formaldehyde glue they compound themselves.

(C) They will see how much of their surroundings is made of these manipulated materials and how little is still in the natural state.

**HIGHLIGHTS**: The soupy cement mixture dries to a hard solid (No. 3, page 196).

The glued wood cannot be separated (No. 13, page 198).

**MATERIALS** (for each team of two)

*Part A–Making cement*
Pan, pie, aluminum, disposable, 7" diameter
Cup, paper, 1 oz. to measure cement and sand-gravel mixture
Cup, paper, about 8 oz. size
Cement powder, 20 ml
Sand mixed with fine gravel, 120 ml
Stick, mixer (tongue depressor, ice cream stick, etc.)
Nail or paper clip

*Part B–Making plywood*
Urea, 7 g
Hydrochloric acid, dilute, 5 ml
Formaldehyde, 25 ml
Beaker, 100 ml–2 are needed
Balance, platform
Cylinder, graduated, 100 ml
Wood, about 4" x 2" x ½" (these dimensions are not critical)
Paper towels–3 are needed
Funnel, glass
Ring stand
Ring
Filter paper, 4" or 5"
Rod, stirring, glass

**Preparation of Materials**

A sack of cement powder would probably be enough for several years. It will keep if stored in a dry place. As this consumes storage space, you might want to try your school maintenance department for lesser amounts before going to local building supply outlets.

A liter of dilute hydrochloric acid is prepared by adding 258 ml of concentrated acid to 742 ml of water. The precise volumes are not critical for our purposes. Protect your clothing from the concentrated acid.

**TEACHING TIPS**

**Responses to Expect**: Response to the theme of this investigation is tempered by the background of students. Suburban or rural areas may produce some resistance to the idea of the man-made environment, while the inner city dweller may take things so much for granted that he can't see the synthetic forest for the artificial trees.

**Practical Hints:** Watch that the concrete mix is not too sloppy. Water should be added cautiously. Stop adding water as soon as the mixture is pliable.

Spend a few moments going through folding a filter paper and placing it in a funnel. This will be new to many students, although some may have coffee makers that use filters at home.

When gluing the wood together with the urea-formaldehyde resin, be sure the ingredients are well mixed before applying them to the wood. Have the students protect their tables with paper towels or newspaper.

**Discussion and Review:** As the students look about them and see that everything has been either painted, molded, formed, fused, poured, or concocted, they will be able to appreciate how little of their surroundings are the same as when man first encountered them.

To have students look ahead, begin wondering at this time what it takes to shape the environment into the forms we want.

## ENRICHMENT

1. Students may want to try some free form sculpture with the concrete mix.

2. Have a student try different proportions of sand, gravel, cement, and water in making concrete. Let him report on the properties of the products obtained.

3. Have students bring in different samples of common synthetic glues. Let them compare the glues for strength in some standardized test that the students devise.

## REFERENCES

### Books

Buehr, Walter, *Plastics, the Man-Made Miracle.* New York: William Morrow and Co., Inc., 1967.

Giffin, Frank, and E. Osers, *The Boy's Book of Modern Chemical Wonders.* New York: Roy Publishers, Inc., 1966.

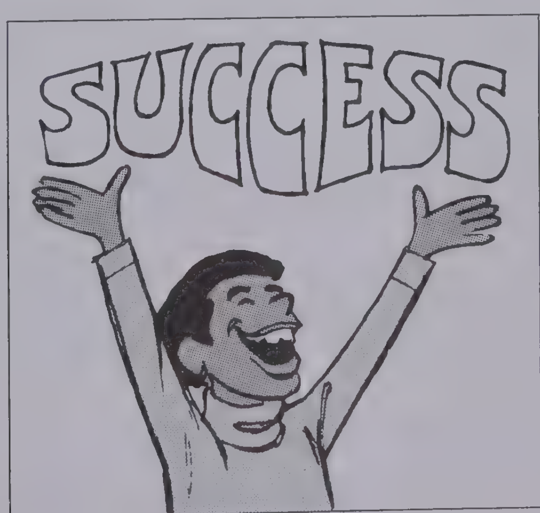
Kaufman, Morris, *Giant Molecules: The Technology of Plastics, Fibers, and Rubber.* Garden City, N.Y.: Doubleday & Co., Inc., 1968.

Wohlrabe, Raymond A., *Exploring Giant Molecules.* Cleveland: World Publishing Co., 1969.

### Multi-Media Aids

*Glass: From the Old to the New Through Research:* 16 mm film, 20 min., EBF B/W: Cat. No. 777, Color: Cat. No. 766.

*Synthetic Fibers–Nylon and Rayon:* 16mm film, black and white, 14 min., EBF Cat. No. 435.



**POSSIBLE ANSWERS**

1. Students' answers: (Wood, plaster, paint, glass, steel, formica, vinyl, asbestos tile, etc.)
2. One or two (or none).
3. Students' answers. (You can't see the powder; it's all stuck together, etc.)
4. Students' descriptions. (Gray, hard, lumpy, rough, etc.)
5. You couldn't get it back completely.
6. Man-made.
7. Man-made.
8. The crystals dissolve (or disappear).
9. The liquid turns white.
10. It is warm.
11. A new substance is forming.
12. It is white and mushy (pastey or gooey).
13. The pieces of wood are stuck together.
14. It's made by gluing thin layers of wood together.
15. (Student answers will vary, but the answers should tend to show little unchanged, depending upon the locale.)
16. Mostly man-made. (Will vary.)
17. Not everything in the man-made environment is good: we have DDT poisoning, air pollution, etc.

**CONCEPT SUMMARY**: We are surrounded by a man-made environment.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 4 (1½ periods)

**PURPOSE**: Show that in order to produce work, energy changes form.

**DEVELOPMENT**: (A) Students will observe the deflection of a compass needle when a current carrying wire is brought near it. (B) They will make some electrochemical cells.

**HIGHLIGHT**: The compass needle moves, indicating that the copper and magnesium produced electricity (Nos. 12 and 13, page 203).

**LOOK AHEAD**: Do not have students disassemble the coil of wire from around the compass, as it will be used as a current detecting device in Investigations 5 and 9.

**MATERIALS** (for each team of two)

*Part A–Magnetic field of a current*
Magnet, cylindrical
Compass, magnetic
Battery pack, 4 flashlight D cells
Bulb, flashlight
Socket, flashlight
Wires, clip leads–2 are needed

*Part B–Electrochemical cell*
Wire, copper, enameled, B&S No. 24, about 20 feet
Wood, ¼" x 2" x 2"–2 are needed to make stand for compass and coil
Magnesium ribbon, 4 inch strip–2 are needed
Copper strip, about 4" x ½"–2 are needed
Sandpaper, fine grit, about 9 square inches
Beaker, 100 ml–2 are needed
Sodium chloride, technical, 1 teaspoon
Rod, stirring, glass
Tape, masking, 10" long
(Compass and clip leads from part A)

*Optional:* Miscellaneous metal strips such as aluminum, lead, zinc to supplement the magnesium and copper

**MATERIALS** (for the class)

*Part A*
Bulb, 40 watt–3 or 4 are needed per class
Socket, with 6 feet of lampcord and plug–3 or 4 are needed per class

**TEACHING TIPS**

**Responses to Expect**: Compasses are usually fun, and some enterprising students may figure out a way to make one keep spinning around by starting and stopping the current in the wire at just the right time. Rather than jump all over them, keep these on tap for Investigation 6, when the electric motor is studied.

**Practical Hints**: Some question may be raised about using larger pieces of metal in the simple cells. Students should soon see that the sizes of the electrodes don't affect the voltage when they try different sizes of metal strips. Then ask what is the advantage of larger electrodes. Answer, of course: increased operating time, or capacity.

This would be a good time to show a "dissected" dry cell or dismantled automobile battery.

In part B, once the compass coils are made they may be used by other classes, unless you want students from all classes to have the experience of making them.

Don't let the usual preoccupation with electricity eclipse the other forms of energy in this investigation.

**Discussion and Review:** The points to make are: The magnetism didn't appear until current went through the lamp; the lamp didn't glow or get hot until current went through it; and the cell didn't put out current until the magnesium ribbon began reacting chemically.

Putting all this together gives us the picture of changing energy as the active agent in doing work.

## ENRICHMENT

1. Have a student demonstrate a series of different combinations of materials to see which makes the best cell.

2. Have a student present information on the different combinations of materials used in commercial cells.

3. Have a student duplicate some of the work of Joule, and show that the mechanical work of stirring water will finally warm the water.

## REFERENCES

### Books

Boumphrey, Geoffrey M., *Engines and How They Work.* New York: Franklin Watts, Inc., 1967.
Sterland, E.G., *Energy into Power.* Garden City, N.Y.: Natural History Press, 1967.
Weiss, Harvey, *Motors and Engines and How They Work.* New York: Thomas Y. Crowell Co., 1969.

### Multi-Media Aids

*Electricity from Chemicals:* 16mm film, color or black and white, 13½ min., Coronet Films Cat. No. 1659.
*Electricity: Measurement:* 16mm film, color or black and white, 12 min., Indiana University.
*Measurement of Electricity:* 16mm film, color or black and white, 11 min., Coronet Films Cat. No. 217.

## POSSIBLE ANSWERS

1. No.
2. 1%.
3. Heat.
4. The needle turns (moves, turns part way around).
5. The needle turns.
6. The needle turns the other way.
7. Students' predictions. (It will turn more.)
8. The needle turns farther (more, faster).
9. Magnetism (and movement).
10. No.
11. No.
12. Yes.
13. Yes.
14. It moved more in salt water than in pure water.
15. No. Nothing happens if the two metals are the same.
16. Students' results.
17. Yes.
18. Electrical energy.
19. It provides electricity (electrical energy, etc.).
20. Heat.
21. Mechanical energy (energy of motion).
22. It changed from one form to another.

**CONCEPT SUMMARY:** Energy changes form as it does useful work.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 5 (1½-2 periods)

**PURPOSE**: Show how energy is converted to electricity through magnetism.

**CAUTION**: In this and the following investigation flashlight batteries will be used in circuits that draw large currents. In the interest of preserving the batteries for later use, tell students to leave them hooked up only while making observations. After writing answers to questions, students can reconnect the batteries when going on to the next question.

**DEVELOPMENT**: Students will generate electricity by the interaction of a conductor with both (A) a permanent magnet and (B) an electromagnet. (C) They will continue to add flashlight bulbs in parallel to a fused circuit until the fuse burns out.

(D) Producing electricity from magnetism will be seen as another instance of energy changing form.

**HIGHLIGHT**: Electricity is produced when the magnet is thrust through the coil (No. 3, page 206).

**MATERIALS** (for each team of two)

*Part A–Electricity from a permanent magnet*
Copper wire, enameled, B & S No. 24, 10 feet
Magnet, cylindrical
Sandpaper, fine grit, 9 square inch piece
Wires, electrical connecting, 24 inches long–2 are needed
Compass, magnetic
Compass coil and stand (from Inv. 4)

*Part B–Electricity from an electromagnet*
Spike electromagnet from Idea 3, Inv. 2
Battery pack, 4 flashlight D cells in series
(Coil made in part A)
(Sandpaper and electrical connecting wires from part A)

*Part C–Fuse protection*
Sockets, flashlight bulb–4 are needed
Bulbs, flashlight–4 are needed
Fuse or fuse wire (to melt when 3 or 4 flashlight bulbs are in parallel)
(Wires, electrical connecting–from parts A and B)

**Preparation of Materials**

The size of the fuse wire will depend upon the light bulbs used. If low current bulbs (0.06 amperes) are used, a 0.2 ampere fuse or fuse wire will be needed. If the higher current bulbs are used (0.35 amperes), then about a one ampere fuse or fuse wire should be provided.

*The wires from compass coil to induction coil should be long enough so that the compass needle deflects only from the magnetic field of the induced current, and not from the field of the magnet itself.* You will probably need about two feet between compass coil and induction coil.

**TEACHING TIPS**

**Responses to Expect**: Some students may think the magnet is moving the needle in the "meter" directly. They can prove this is not so by disconnecting one wire from the coil and seeing that the motion stops.

A student may bring up the perennial question about connecting a motor to a generator and back to the motor again. Ask whether he thinks all the energy going into the motor is used to turn the generator and all the energy going into the generator comes out to turn the motor. If this is too deep, start by asking if motors and generators get warm. When he agrees to this, then ask if this energy can be used by the motor or generator for anything else.

**Practical Hints:** Watch connections. Students frequently do not make good connections and then cannot see anything happening. An oxide layer that should be scraped off may form on metal. A few wipes with fine sandpaper is a quick remedy.

While fuse wire does not provide a serious hazard, caution students about touching hot wire. See that the wire is over something that won't be damaged.

If your storeroom has a demonstration generator with a crank and light bulb, let the students use it at this time. When they note that the faster they crank, the brighter the light glows, ask when they are putting in the most energy. Useful at this point would be bicycle light generators and the hand operated "explorer's flashlights" that were popular a few years ago.

**Discussion and Review:** The conversions of energy from one form to another is old stuff by now. Here then is a special kind of conversion, motion to electricity. Usually electricity has a little extra something for many students. They should come to see that electricity produces magnetism and vice versa.

The material on fuses and safety is important in terms of survival. Electrical fires make up an appreciable part of total fires. Depict fuses as a source of protection and security, rather than another thing to worry about.

## ENRICHMENT

1. Have a student discuss and demonstrate circuit breakers.

2. Have a student make a simple generator by mounting a magnet so it can be rotated on the end of a stick near a coil.

3. Have a student demonstrate an automobile generator and alternator. Have him explain the difference.

## REFERENCES

### Books and Articles

Bennett, Alan, R. Herkes, P. Kemens, and A. Maradudin, *Electrons on the Move.* New York: Walker & Co., 1964.

Hellman, Hal, *Light and Electricity in the Atmosphere.* New York: Holiday House, Inc., 1968.

Kearney, Paul W., *When Kilowatt Becomes Killer Watt.* (Pamphlet). New York: Berk & Co., 1959.

Lewis, Floyd A., and Henry H. Urrows, *The Incandescent Light.* New York: Shorewood Publishing, 1961.

Mix, Floyd, and E.C.Pritchard, *All About House Wiring*, rev. ed. Homewood, Ill.: Goodheart-Wilcox Co., Inc., 1968.

### Multi-Media Aids

*Electricity: Distribution:* 16mm film, color or black and white, 15 min., Indiana University.

*Electricity: How It Is Generated:* 16mm film, color or black and white, 11 min., Coronet Cat. No. 1301.

*Electricity: Production:* 16mm film, black and white, 16 min., Indiana University.

*Electricity: Principles of Safety:* 16mm film, black and white, 11 min., Coronet Cat. No. 1305.

*How to Produce Electric Current with Magnets:* 16 mm film, 11 min., EBF B/W: Cat. No. 1883, color: Cat. No. 1882.

*My Pop's a Lineman:* 16mm film, color, 16 min., International Film Bureau Cat. No. 21 FB 207.

*Series and Parallel Circuits:* 16mm film, black and white, 11 min., EBF Cat. No. 259.

*Superconducting Magnets:* 16mm film, color, 12½ min., Atomic Energy Commission.

**POSSIBLE ANSWERS**

1. Students' predictions. (Magnetism can produce electricity.)
2. Electricity was passing through the compass coil.
3. Yes.
4. Electricity was passing through the compass coil.
5. Made no difference.
6. Electricity was produced.
7. Put a flashlight bulb in place of the compass coil, and see if it lights up.
8. Use a more powerful magnet; insert the magnet into a coil that has more loops in it; move the magnet back and forth faster.
9. Students' predictions. (*Yes* or *no*.)
10. The needle moves while the nail is being put into the coil.
11. The needle moves back and forth.
12. No difference, unless electricity by the one method seems stronger than by the other.
13. The lamp lights.
14. The wire melts after several bulbs are connected. (The number of bulbs depends upon the size of the fuse wire and how much current the bulbs take.)
15. Students' observations.
16. There was too much electricity (for the fuse wire).
17. The wire would get hot (melt, burn).
18. You could overload the wires.
19. The wires might get hot enough to set the house on fire.
20. You had to move the magnet.
21. Energy.
22. Energy has changed from one form to another.
23. Energy in a different form.
24. Each one will produce the other. (Electricity makes magnetism and vice versa.)

**CONCEPT SUMMARY**: Energy is converted to electricity by magnetism.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 6 (2-2½ periods)

**PURPOSE**: Show how electromagnetic forces are used to do work.

**DEVELOPMENT**: (A) Students will study the behavior of magnets and with this study as a basis (B) they will construct a simple operating model of a motor.

**HIGHLIGHT**: With practice in working the switch, students are able to make the armature of their self-constructed motor turn continuously for a few revolutions (No. 15, page 215).

**MATERIALS** (for each team of two)

*Part A–Magnetic forces*
Magnet, cylindrical
Compass, magnetic
Battery pack, 4 flashlight D cells
Wires, clip leads–2 are needed
Tape, masking, 4"
Spike electromagnet (from the last investigation)

*Part B–Electric motor*
Paper clip, standard size–2 are needed
Sandpaper, fine grit, 9 square inches
Beaker, glass, 600 ml
Cardboard, manila folder, 5" x 10"
Scissors
Compasses, geometry
Ring stand
Clamp, burette
Test tube, Pyrex, 18mm x 150mm
Tape, masking, 18" length
(Battery pack, clip leads, magnet, spike electromagnet from part A)

**TEACHING TIPS**

**Responses to Expect**: There will be a wide range of reactions, as some students have had experience with magnets while others have not. They all enjoy "chasing" one magnet with another across a smooth table top.

There is usually a surge of enthusiasm when the first team to do so gets their motor "shaft" turning a few turns. It gives impetus to the other groups to get their's going.

**Practical Hints**: If the magnets are dropped frequently they will lose magnetism. The student constructed motors won't work if the magnets are weak. It may be necessary to have a remagnetizing circuit available.

Try to find a surplus radar magnet. These are extremely powerful and may startle some students who try to remove small iron objects from them. Challenge students to pass a screwdriver or similar magnetic object between the poles of the magnet without touching one of the poles.

CAUTION: KEEP WRISTWATCHES WELL AWAY!

Have around some of the tiny battery-powered motors being imported from Japan. These have permanent magnets that will pick up paper clips, etc., and are frequently used in toys.

If you can afford it, buy a St. Louis motor for demonstration purposes from any of the common scientific supply companies. It will provide an additional step in the progression from crude model motor to the commercial motor.

**Discussion and Review:** Remember it is the forces generated by the interacting magnetic fields that enable motors to do work.

A possible stumbling block is the idea that forces can act over a distance in a circular manner. If a motor winding up a weighted string is not enough, go back to the windlass used on wells and the anchors of old sailing ships. If a student walks in a circle pushing something, he will be convinced he has done work.

## ENRICHMENT

1. Have a student demonstrate different kinds of motors, such as series and shunt wound motors or the synchronous types used on AC only.

2. Have a student connect an electric clock to an electric power source of variable frequency. Compare it to another electric clock plugged into the 60 cycle wall outlet to show that the motor speed is dependent on the source's frequency. Students are usually interested in watching the variable source make time slow down and speed up.

3. Have a student compare the ability of various materials to shield magnetism. They may be surprised at magnetism passing through materials such as aluminum.

## REFERENCES

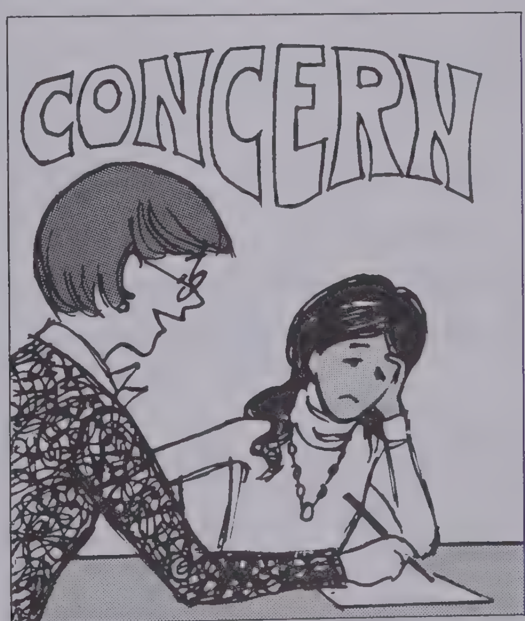
### Books and Articles

Basford, Leslie, and Joan Pick, *Lightning in Harness: Foundations of Electricity.* London: Sampson, Low, Marston & Co., 1966.

General Electric, *Fundamentals of Motors.* 8pp. Catalog No. A-60.

### Multi-Media Aids

*Magnetism and Electricity:* 16 mm film, 17 min., McGraw-Hill, B/W: Cat. No. 653210, color: Cat. No. 653310.



**POSSIBLE ANSWERS**

1. Students' answers. (Either clockwise or counterclockwise, depending upon which end they happen to point toward the compass.)
2. Students' answers. (In the opposite direction to their answer to question 1.)
3. One magnet pushes on the other. (They repel.)
4. They repel.
5. The one magnet pulls toward the other. (They attract.)
6. Like poles repel, unlike poles attract.
7. Students' answers. (Either *toward* or *away*, depending upon which way they happen to have hooked up the battery pack.)
8. Students' answers. (Like the marked pole, if there is repulsion; like the unmarked pole, if there is attraction.)
9. Students' answers. (Opposite of the answer for question 7.)
10. Students' answers.
11. Will be repelled.
12. Students' answers.
13. Yes, since magnetism from the electromagnet seems to be similar to magnetism from the bar magnet.
14. Bar magnet swings over toward the spike.
15. The other end of the bar magnet swings over.
16. It would be stronger, would turn faster.
17. Strong motors use more electricity, have more magnets, etc.
18. They don't pollute the air.
19. The answer is variable, depending on region: 70% for Los Angeles; 50% for eastern coal-burning areas.
20. The human race will die out.
21. Demand for energy sources is increasing at a greater rate than supply; oil and gas wells are drying up.
22. Atomic energy, solar batteries.
23. The pushes and pulls.
24. The changing position (the distance).
25. It produces motion, makes motors possible, runs things, can do work, etc.

**CONCEPT SUMMARY**: Interacting electricity and magnetism do work.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 7 (2-2½ periods)

**PURPOSE**: Study those interactions between different forms of matter which provide a basis for understanding what keeps ships afloat and planes aloft.

**DEVELOPMENT**: (A) Students will make weight and water displacement measurements for objects buoyed up in water; (B) they will study the lifting effects of unequal air pressures; and (C) they will observe the effect upon a "passenger" of suddenly starting and stopping a toy truck.

**HIGHLIGHTS**: The ball doesn't come out of the funnel (No. 7, page 220).

Blowing between strips of paper makes them come together (No. 24, page 222).

**MATERIALS** (for each team of two)

*Part A–Buoyancy*
Balance, spring, 250 g capacity
Cylinder, graduated, 100 ml
String, 3 foot length (to be also used in part C below)
Miscellaneous objects, weighable on the spring balance, small enough to get into the graduated cylinder, some that sink, others that float–4 to 6 different objects, such as corks, fishing sinkers, metal cylinders, etc.

*Part B–Air Lift*
Funnel, glass
Ball, Ping-Pong
Cup, paper, 8 oz.
Beaker, 400 ml
Tape, masking, 4" length
Paper clip, standard size
Cardboard, manila folder, 5" x 3"
Paper, 11" x 3"–2 sheets are needed

*Part C–Inertia*
Cylinder, metal, 2" x about 1" diameter
Cart (Hall's carriage, toy truck, etc.)
(String, 3 foot length from part A above)

**TEACHING TIPS**

**Responses to Expect**: The biggest surprise is the ball not coming out of the funnel. This is true even for the scientifically more sophisticated students. It defies "common sense" even though they may have seen it before. Ask what this has to do with winning the World Series.

If there is a source of compressed air in the laboratory, connect a length of rubber tubing to it and hold the end straight up. Set a Ping-Pong ball in the air stream. Show the class that the ball will stay in the stream by moving the end of the hose about. Ask if this is consistent with their results with the ball and funnel and the strips of paper. If there is a question about how it works, approach a solution by asking "Which side of the ball has the fastest air current when it starts to fall out of the stream?"

In talking about inertia, use familiar situations in the automobile. The way things slide about when starting or stopping is one example. The older and wiser boys who drive know that a sharp right turn will slide the girl in the passenger's seat closer to them, but use this approach with discretion.

**Discussion and Review**: When looking at air movement and pressure, mention Daniel Bernoulli, the discoverer of these concepts. Ask if he was trying to invent an airplane or simply trying to find some order in nature when he made his discoveries in the mid-Eighteenth century. It may provide an answer to the question "What good is knowing that?" since it demonstrates that knowledge, which at first seems to have no practical value, frequently turns out to be useful.

## ENRICHMENT

1. Have a student use a vacuum cleaner and a light plastic ball to demonstrate how the air stream and object interact.

2. Have a student demonstrate model airplane flight and different airfoil shapes.

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### Books and Articles


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Bowen, Ezra, and Wilfred Owen, *Wheels.* New York: Time-Life Books, 1967.

Calder, Richie, *The Evolution of the Machine.* Eau Claire, Wisc.: E.M. Hale & Co., Inc., 1968.

Coombs, Charles, *Motorcycling.* New York: William Morrow & Co., Inc., 1968.

Halacy, D.S., Jr., *Energy and Engines.* Cleveland: World Publishing Co., 1967.

Kearney, Paul W., *Highway Homicide.* New York: Thomas Y. Crowell Co., 1966.

Lewis, Edward E., and Robert O'Brien, *Ships.* New York: Time-Life Books, 1965.

McEntee, Howard G., *The Model Aircraft Handbook,* rev. ed. New York: Thomas Y. Crowell Co., 1969.

Taylor, Fred E., *How to Avoid Automobile Accidents.* New York: Crown Publishers, Inc., 1968.

Yerkow, Charles, *Automobiles: How They Work.* New York: G.P. Putnam's Sons, 1966.


### Multi-Media Aids


*Airplanes: Principles of Flight:* 16mm film, color, black and white, 11 min., Coronet Films Cat. No. 1215.

*Archimedes' Principle:* Super-8mm film loop, color, 2¼ min., Ealing Films Cat. No. 82-0027/1.

*Boats: Buoyancy, Stability, Propulsion:* 16mm film, color, black and white, 13½ min., Coronet Films Cat. No. 1182.

*Broken Glass:* 16mm film, color, 13 min., International Film Bureau Cat. No. 2CAL57.

*The Buoyant Force:* Super-8mm film loop, color, 3½ min., Ealing Films Cat. No. 82-0019/1.

*Fatal Meeting:* 16 mm film, color, 16 min., International Film Bureau Cat. No. 2 CAL55.

*Floating and Sinking:* Super-8mm film loop, color, 3½ min., Ealing Films Cat. No. 82-0035/1.

*Laws of Motion:* 16 mm film, 13 min., EBF B/W: Cat. No. 751, color: Cat. No. 576.

*Where Mileage Begins:* 16mm film, color, 26 min., General Motors Corp.


**POSSIBLE ANSWERS**

1. Lose weight.
2. They are the same.
3. It pushes back up with the same force.
4. An amount equal to the weight of the object.
5. Shape the steel so it pushes away an amount of water equal to the steel's weight.
6. The ball stays in the funnel.
7. The ball stays in the funnel.
8. The ball falls out.
9. Students' predictions.
10. The bottom part of it was pushed over toward the hole.
11. It was the same.
12. It was less on the side of the hole.
13. The paper fluttered up.
14. On the bottom.
15. Along the top side.
16. Students' predictions. (Most students will predict *away from you.*)
17. It moved away.
18. Students' guesses.
19. Direction L.
20. On the other side.
21. The side where it is moving slower.
22. Inside.
23. Students' predictions. (Together.)
24. They move together.
25. Along the top.
26. Along the top.
27. On the bottom.
28. The greater air pressure pushing up on the bottom of the wings.
29. It fell over (or moved backwards).
30. It fell over (or moved forward).
31. To keep from hitting the dash or windshield if there's a sudden stop. To hold you in your seat, etc.
32. To know how cars will act so you can control them better.
33. Interact with the water.
34. Interact with the air.
35. The interactions of the different forms of matter.

**CONCEPT SUMMARY**: Transportation is made possible by understanding how different forms of matter interact.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 8 (2 periods)

**PURPOSE**: Show how interacting electricity and magnetism produce sound.

**DEVELOPMENT**: (A) Students will make their own telegraph sender. (B) A coil attached to a stretched parchment will become a crude speaker when a magnet is placed in the coil. Alternating current fed to the coil will produce an audible hum. (C) They will examine the inside of an earphone.

**HIGHLIGHT**: The homemade speaker can produce sound (No. 6, page 228).

**MATERIALS** (for each team of two)

*Part A–Telegraph sender*
Spike electromagnet (from Idea 3, Inv. 2)
Wood, 6" x 4" x 1"
Rubber band, 3" long
Rubber strip (from a rubber band), 1" length
Tape, masking, 14" length
Switch, knife
Strip, iron, 2" x 1/2" x 1/16"
Battery pack, 4 flashlight D cells
Wire, lampcord, 10 foot length (2 wires insulated from each other)
Sandpaper, fine grit, 9 square inches

*Part B–Loudspeaker*
Hoop, embroidery, 5" diameter
Paper, parchment, to fit over hoop
Tape, masking, to attach paper to hoop, 10" length
Wire coil (from Inv. 5)
Magnet, cylindrical

*Part C–Earphone*
Earphone
(Battery pack from part A)

**MATERIALS** (for the class)

*Parts B and C*
Transformer, with line cord and plug, 115 v to 10 v, 60 cycle

**TEACHING TIPS**

**Responses to Expect**: Let the students get the telegraph clicking out of their systems for a few minutes rather than trying to repress their curiosities. It will be easier to get down to business.

Students will want to know about other sounds and will have questions about their speakers and earphones. If an audio oscillator (signal generator) is available, let them hook it to their earphones. It probably will lack the power to run their speakers.

**Practical Hints**: If the students leave the batteries connected to the electromagnets for periods of time longer than a very few minutes, the cells will run down. Often, a few hours rest will give the chemicals inside a chance to restabilize and the cells will then operate again for some time. Don't let a few cells or the few cents they cost inhibit the student who is starting to explore. The value of this is incalculable.

When assembling the speaker be sure the paper used is reasonably stiff and stretched taut. A limp diaphragm is not effective.

Don't leave the transformer plugged in too long at any one time. It will overheat.

Have around for viewing an old speaker out of a jettisoned radio or TV. If old, and someone pokes a finger through the paper cone, it will not be a tragedy or a traumatic experience.

Have a copy of the Morse code in the room for any ardent telegraphers who wish to try sending messages. It may be found in the *Amateur's Radio Handbook,* which should be in your school library.

**Discussion and Review:** While the concept in this investigation is simply about producing sound, foundations of the idea can be prepared by asking during discussion what we can do with sound from these devices. The answer—communicate—will have to be sorted from others, such as be entertained, talk to people, or even send messages.

## ENRICHMENT

1. Have a student demonstrate different kinds of speakers, such as woofers and tweeters.

2. Have a student demonstrate the difference between ordinary and hi-fi earphones by sending high pitched sounds through each.

3. Challenge students to assemble speakers that can pass the highest or lowest notes.

4. Use an audio oscillator (a signal generator) and either speaker or earphones to let students find what range of frequencies they can hear.

## REFERENCES

### Book

Marcus, Abraham and William, *Elements of Radio,* 5th ed. Englewood Cliffs, N.J.: Prentice-Hall, Inc., 1965. Chapters 7 & 22. These chapters are devoted to earphone and speaker operation.

### Multi-Media Aids

*Telegraph Circuit:* Transparency, School Products Co., Inc. Cat. No. Sc8351.
*Telephone Handset:* Transparency, School Products Co., Inc. Cat. No. Sc8352.
*Your Voice and the Telephone:* 16mm film, color, 7 min., Bell System Cat. No. 59900.

## POSSIBLE ANSWERS

1. The nail becomes magnetized and attracts the iron.
2. The magnetism turns off.
3. What the clicks mean (a code, etc.).
4. Current won't flow and work the sounders if both keys (switches) are not closed at the same time.
5. Magnetism.
6. The paper vibrates and produces sound.
7. A speaker.
8. Electricity and magnetism.
9. It clicks. (Makes a noise, etc.)
10. A hum. (The same pitch as from the speaker.)
11. A magnet.
12. Coils of wire (and magnets).
13. Magnetism.
14. Electricity and magnetism.
15. Magnetism (and sound).
16. Electricity and magnetism.

**CONCEPT SUMMARY:** Interacting electricity and magnetism can produce sound.

**PURPOSE**: Develop the concept that sound may be converted to electrical signals.

**DEVELOPMENT**: (A) Students will vibrate a ruler to produce sound. (B) By successively adding more bulbs in a series circuit they will study the effect of resistance on current. (C) They will note the effect of pressure on the resistance of carbon particles. (D) Using common, inexpensive materials, students will construct a microphone that operates on the principles learned in the earlier parts of the investigation.

**HIGHLIGHTS**: The fewer the lights in the circuit, the greater the current (No. 18, page 231).

Squeezing the carbon particles makes the bulb burn brighter (No. 23, page 233).

Touching, blowing, or speaking into an assembly of carbon granules, plastic, and wire produces sounds (No. 34, page 235).

**MATERIALS** (for each team of two)

*Part A–Vibrating a ruler*
Ruler, 12" metric
Rubber band, 3" length

*Part B–Flashlight bulbs in series*
Flashlight bulbs–4 are needed
Sockets, flashlight bulb–4 are needed
Compass, magnetic
Compass coil and stand (from Inv. 4)
Battery pack, 4 flashlight D cells
Wires, clip leads–3 are needed
Tape, masking, 4" length

*Part C–Pressure and the resistance of carbon particles*
Paper clips, standard size–2 are needed
Beaker, 100 ml, *plastic*
Carbon particles
Tape, masking, 4" length
(Battery pack, flashlight bulb, clip leads, and socket of part B)

*Part D–Microphone*
Sandpaper, fine grit, 9 square inches
Microphone kit (Parts are illustrated in the text)
Earphone
Lampcord, 10 foot length
Tape, masking, 2" length
(Battery pack, clip leads from parts B & C)

**TEACHING TIPS**

**Responses to Expect**: In part A, the ruler twanging and the rubber band plucking will be old hat to some students. Let them play for a few moments, then pin down the essentials of this activity. Ask the inevitable guitarists which way they fret to get higher or lower notes.

Part B (the effect on the current of the number of bulbs in series) won't mean much until the carbon is squeezed in part C. This is quite dramatic and will stir up some action, but the real peak is actually hearing voices through the earphones in part D.

**Practical Hints**: Try giving different thicknesses of rubber bands to different groups. See if they correlate pitch with the size of rubber band. The guitarists will be able to shine here as they talk about thick and thin strings.

Borrow a xylophone from the physics lab (these are often called "gamut bells") and let the class discover that size and pitch are inversely related here too. Students can also feel the metal bars vibrate.

Place a Petri dish half filled with water on an overhead projector. Touch the tines of a vibrating tuning fork to the water. The class will see the burst of spray and sometimes a series of waves in the water between the tines. The spray will emphasize the motion associated with sound.

Use a string of Christmas tree lights to augment the discussion of the current in circuits. Show that if you short out one of the lights (with a piece of wire, for example) the rest of the lights get brighter. CAUTION: DON'T OVERDO THIS AS THE OTHER BULBS WILL BLOW OUT. Be sure to get the type of lights that are wired in series, where unscrewing one bulb will turn off the string.

Let the different groups try to tie as many of their circuits together as they wish. It will give students some appreciation of the complexities of telephone systems, something most take for granted.

**Discussion and Review:** Remember that sound and vibrations, current and resistance, and the unique properties of carbon are not the concept. They are but the blocks we are using to build an idea about turning sound into an electric signal that can be sent from place to place. In other words, we are establishing communications as the outgrowth of learning about all these other things.

## ENRICHMENT

1. Have a student demonstrate sound differences, using such items as glass bottles or other containers filled with different amounts of water. Students could strike them or blow across the open tops.

2. Compare the pitch of a slide whistle with the length of the column of air inside as the slide is moved.

3. Have a student demonstrate a microphone connected to an oscilloscope.

## REFERENCES

### Books


Denes, Peter, and Elliot Pinson, *The Speech Chain.* Baltimore: Williams & Wilkins Co., 1963.

Kogan, Philip, and Joan Pick, *The Silent Energy: Foundations of Electrical Technology.* London: Sampson, Low, Marston & Co., 1966.

Stevens, S.S., and Fred Warshofsky, *Sound and Hearing.* New York: Time-Life Books, 1965.


### Multi-media Aids

*Fundamentals of Acoustics:* (2nd ed.) 16mm film, black and white, 11 min., EBF Cat. No. 478.
*Sounds All About Us:* 16mm film, color or black and white, 11 min., Coronet Films Cat. No. 805.
*Sound Waves and Their Sources:* (2nd ed.) 16mm film, black and white, 11 min., EBF Cat. No. 477.

**POSSIBLE ANSWERS**

1. A (twangy) sound.
2. Moved back and forth (vibrated).
3. A higher sound (pitch).
4. Faster.
5. It's higher.
6. It's even faster.
7. They are about the same.
8. The short side.
9. The short side.
10. Vibrating.
11. It vibrates.
12. It vibrates.
13. It must vibrate.
14. Students' observations.
15. Students' observations. (It should be a larger number than the answer for "14.")
16. Students' observations. (Should be larger number than for "15.")
17. Students' observations. (Should be larger number than for "16.")
18. It became larger.
19. It gets smaller.
20. It increases the amount of the resistance.
21. The current becomes smaller.
22. It increases.
23. It burns more brightly.
24. It burns less brightly.
25. It becomes greater.
26. The resistance becomes smaller.
27. The bulb flickers.
28. The bulb would get brighter and dimmer 100 or 1,000 times a second.
29. The carbon particles. (The pieces of carbon.)
30. The battery pack.
31. It'll become greater because the carbon particles will be squeezed together more (the resistance will decrease and hence the current will increase).
32. The electromagnet in the earphone will become stronger and weaker, causing the metal disc to move in and out.
33. You hear static.
34. Students' responses. (If the nut and bolt are properly adjusted for the amount of carbon particles, students should hear static.)
35. A block (quarter mile, etc.).
36. All over the world.
37. Electrical vibrations (currents).
38. It changes sound vibrations into electrical vibrations.

**CONCEPT SUMMARY**: Sound is converted to electrical vibrations for communication.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 10 (2-2½ periods)

**PURPOSE**: Develop the concept of sending coded information through space to form the pictures of television.

**DEVELOPMENT**: As a basis for understanding simulated motion, students will examine (A) motion picture film, (B) flip cards, and (C) flashing lights. (D) They will examine the dot pattern of a newspaper photo. (E) They will "draw" an image on paper from a series of coded numbers.

**HIGHLIGHTS**: The pictures on the flip cards seem to move (No. 5, page 238).

The light seems to move from bulb to bulb (No. 10, page 239).

All the numbers can be used to form a picture (No. 19, page 241).

**MATERIALS** (for each team of two)

*Part A–Motion picture film*
No materials needed–film is illustrated in text

*Part B–Flip cards*
Flip cards–a booklet of cards illustrated so that the objects depicted appear to be in motion when the cards are viewed rapidly in sequence. This rapid viewing is accomplished by holding the cards in one hand at the edge where they are bound together, and running the thumb of the other hand successively over the cards' free edge.

*Part C–Blinking lights*
Battery pack, 4 flashlight D cells
Wires, clip leads–2 are needed
Socket, flashlight bulb–6 are needed
Flashlight bulbs–6 are needed
Strip, copper, 4" x ½"–2 are needed
Sandpaper, fine grit, 9 square inches
Tape, masking, 9" length

*Part D–Newspaper photographs*
Newspaper photographs–30 photographs
Magnifying glass

**Preparation of Materials**

In part C, there is more than one way to hook up the flashlight bulbs in parallel. One way is to sandwich one side of the bulbs between two copper strips held together with masking tape.

**TEACHING TIPS**

**Responses to Expect**: Most of today's students have never seen the hand cranked flip card movies of the old Penny Arcades, but then they've never seen Penny Arcades. The little booklets will be new to them. The lights will be more familiar, although they probably haven't thought about them. The psychedelic light shows, which many high school kids go to, may take on more meaning; tie them in to the lights here.

When the picture is decoded, tie it in with the very visible lines on the average TV. Probably all students have seen these. Ask how many have ever looked at a TV screen with a magnifying glass.

**Practical Hints:** Borrow a movie projector and run it with the various dust jackets and covers open. Put it on slow (silent) speed so the shutter action is partly visible. Don't let the bare bulb shine in the students' eyes. At sound speed, 24 frames are shown a second. Each one is repeated three times so students see 72 pictures a second.

In part E, when drawing coded information in black and gray, ask how much more of a code would be needed for color. Students may have trouble believing the basic vision colors are blue, green, and red. Use old filters from the drama department on three flashlights. Show that red and green shining on a screen appear yellow and all three seem white. If your white is not pure it's because the color filters are not always in the optimum part of the spectrum.

**Discussion and Review:** This is a fairly abstract investigation. The idea that a picture is broken down into a code and reassembled will not come easily. Talk about simple codes the students are familiar with, like stop lights and the abbreviations of everyday speech.

## ENRICHMENT

1. Have a student form images with a simple lens to show how the TV camera starts out. Use a variety of focal lengths to show how different effects are achieved.

2. Have two students who know Morse code (draft them from the school radio club, if necessary) send a few messages back and forth with a buzzer. Let the class make up some messages to prove it works.

3. Have some student figure out how many drawings it takes for 10 minutes of a cartoon.

## REFERENCES

### Books


Hellman, Hal, *Communications in the World of the Future.* Philadelphia: J.B. Lippincott Co., 1969.

Rowland, John, *The Television Man: The Story of John L. Baird.* New York: Roy Publishers, Inc.


### Multi-media Aids


*Color Television Tube:* Transparency, School Products Co. Cat. No. Sc-8259.

*Development of Communications:* (2nd ed.) 16mm film, black and white, 10 min., EBF Cat. No. 884.

*Girdle Round the Earth:* 16mm film, black and white, 20 min., International Film Bureau Cat. No. 21FB396.

*How Color Television Works:* Filmstrip, color, 40 frames, Popular Science Publishing Cat. No. 545.

*Television Camera Tube:* Transparency, School Products Co., Inc. Cat. No. Sc-8260.

*Television: How It Works:* 16mm film, color or black and white, 11 min., Coronet Films Cat. No. 647.


**POSSIBLE ANSWERS**

1. Little pictures.
2. Students' descriptions.
3. Very little (or none).
4. Students' answers. (Allow wide latitude.)
5. The drawings seem to move.
6. Nothing (*or* the cards, *or* the student's thumb).
7. Your eyes (brain) fool you. Your eyes can't work that fast.
8. The same thing is happening. (They are all still pictures.)
9. Students' answers. (Give latitude here; it's their guess.)
10. It seems to move.
11. The same idea: it only *seems* to move.
12. There is nothing moving on the screen; it's all still pictures.
13. A picture (of whatever subject is chosen).
14. Light and dark dots (spots of ink, etc.)
15. Light and dark lines.
16. Pictures are formed of light and dark spots (lines, etc.).
17. See where the number lines and letter lines cross.
18. No.
19. A person (a boy).
20. Back a few feet.
21. Back a few feet.
22. Use more boxes and make them smaller; use more shades.
23. The positions of some of the dark and light spots.
24. In your (my) head.
25. Energy and matter.
26. The interaction of energy and matter.

**CONCEPT SUMMARY**: Understanding of interacting matter and energy lets us send pictures through space.

## PHYSICAL SCIENCE IDEA 5: TECHNOLOGY, Investigation 11 (1½ periods)

**PURPOSE**: Develop the concept that understanding technology is necessary to survive in this man-made world.

**DEVELOPMENT**: (A) Students will produce chlorine gas by mixing bleach and ammonia water, (B) will test the flammability of nail polish, and (C) will compare the slipping tendency of rubber-backed and unbacked rugs.

The students will recognize these activities as interactions of matter and energy, and see the survival value of understanding them.

**HIGHLIGHTS**: The mixture of cleansers produces chlorine gas (No. 1, page 244).

Cosmetics burst into flames (No. 4, page 245).

**MATERIALS** (for each team of two)

*Part A–Making chlorine gas*
Chlorine bleach, 15 ml
Ammonia solution, 15 ml
Beaker, Pyrex, 100 ml–2 are needed
Rod, stirring, glass

*Part B–Some matter is more flammable than other matter*
Nail polish, small bottle, 2 ml
Nail polish remover, 2 ml
Burner
Wood, small piece about 4" long and thick enough so that it doesn't burn too fast
Cotton, absorbent, size of a walnut
(Stirring rod and beakers from part A)

**MATERIALS** (for the class)

*Part C–Rug slipping demonstration*
Carpet, 9" square, with rubber backing
Carpet, 9" square, without backing
Balance, spring, 250 g capacity
Paper clip, standard size
Weight, 3 ounces

**TEACHING TIPS**

**Responses to Expect**: The students will react to the smell of the chlorine. They have a tendency to overreact. Don't make a big issue of the squeals and they will drop it.

The flammability of fingernail polish and remover may startle a few. Try igniting the dried polish the girls are perpetually peeling off their nails.

Many of the students will be fascinated by the burning absorbent cotton. Ask them if any of them use it around their Christmas trees.

**Practical Hints**: Get some of the girls to test nail polish from their purses.

Collect swatches of different kinds of cloth and have the students test their rates of burning. Try the home economics department or wives who sew.

Augment the discussion of slipping and falls by having the students compare the stopping power of the various shoe materials they are wearing.

Have the track men talk about their spikes.

**Discussion and Review:** There are two tasks here. One is the concept of this investigation, the problem of survival in the environment. The other is the culmination of the Idea. All the concepts of the investigation should be looked at, to see how the understanding of matter and energy have enabled us to create the world we live in.

## ENRICHMENT

1. Have one or more students clip accident reports for a week. Break them down to different categories, e.g., cars, falls, fires, electrocutions, etc.

2. Have a student interested in electricity report on the wiring codes and their safety features. Discuss grounds and the requirement of a third wire on school equipment.

3. Have a student bring in a package of prepared food, such as potatoes, and read off the contents. Ask if anyone knows what the various chemicals are and whether or not they are harmful.

## REFERENCES

### Books

Carper, Jean, *Stay Alive.* Garden City, N.Y.: Doubleday & Co., Inc., 1965.

Considine, Bob, *Man Against Fire.* Garden City, N.Y.: Doubleday & Co., Inc., 1965.

Greenbank, A., *The Book of Survival.* New York: Harper & Row, 1968.

John Hancock Mutual Life, Inc., *Safety at Home.* Boston: 1952, pamphlet.

Lykes, Norman R., *A Psychological Approach to Accidents.* New York: Vantage Press, Inc., 1954.

### Multi-media Aids

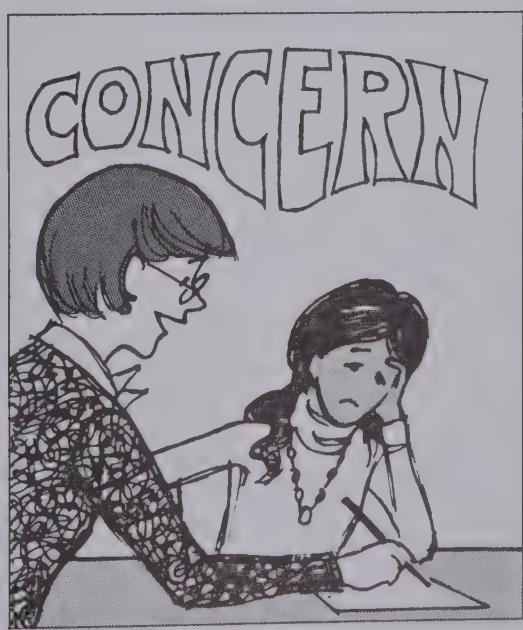
*Experiments in Controlling Brush Fires with Detergent Foam:* 16mm film, color, 6½ min., A.E.C.

*Fire, Cause for Alarm:* 16mm film, color, 12½ min., Bell System Cat. No. 63000.

*Fire Prevention in the Home:* (2nd ed.) 16mm film, 11 min., EBF B/W: Cat. No. 2419, color: Cat. No. 2418.

*Time Out for Trouble:* 16mm film, black and white, 22 min., International Film Bureau Cat. No. 2M56.

*A Way with Fires:* 16mm film, black and white, 30 min., Bell System Cat. No. 40,000.



**POSSIBLE ANSWERS**

1. Chlorine (something that smells bad).
2. You have to keep on your toes. You must know what you are doing to be safe.
3. It burns.
4. Good, hot fire, etc.
5. None, or not many (oil).
6. Yes. Gasoline burns easily. It can even explode if the right amount of air mixes with it.
7. It gets darker, smokes, etc.
8. It burns up and disappears.
9. It (insulates) protects the ironing board, stops the heat flow, etc.
10. We can control when things burn and where.
11. Students' data.
12. Students' data. (Greater than for number 11.)
13. It takes more force to move the piece with rubber backing.
14. The one with the backing. The one harder to slide.
15. High friction so the car would stop sooner.
16. Low friction so you can slide as easily as possible.
17. Energy.
18. Matter and energy.
19. Matter and energy.
20. Students' answers. (Inflammable clothing, cheap brake fluid, bad lamp cords, paint with lead in it, DDT, etc.)

**CONCEPT SUMMARY**: Understanding how matter and energy interact helps us survive in our man-made world.

**IDEA SUMMARY**: Man's understanding of the interactions of matter and energy can bring him comfort, safety, leisure, and plenty.

# LABORATORY MATERIALS FOR IIS PHYSICAL SCIENCE

## GENERAL

On the following pages there are two complete lists of laboratory materials: List #1 and List #2.

List # 1 was designed to make ordering materials as easy as possible for the teacher. It is divided into 10 groups of materials, the grouping being based primarily on the places from which the materials can be obtained.

List # 2 is an alphabetical list indexing the items given in List #1. While List #1 will be convenient for ordering materials prior to the year of their use, List # 2 will be convenient for referring to items in List #1 should the need arise during the course of the school year.

*List # 1*—In List # 1 a distinction is made between two types of materials: the first 4 groups of materials are designated **EQUIPMENT** and the remaining 6 groups are designated **SUPPLIES.**

**EQUIPMENT**—All materials that can be used more than one year. Once ordered they will not have to be reordered until they wear out or break. Examples: balances, beakers, magnets.

**SUPPLIES**—All materials that either are used up or are fragile enough so that they are not likely to last more than a year. The teacher will need to reorder these materials each year. Examples: filter paper, magnesium ribbon, batteries.

## ORDERING MATERIALS

*Determining the quantities of equipment you need to order*–In List #1, quantities are followed by one of three different labels. For example, you will find:

| Item | Quantity | Label |
|---|---|---|
| Geiger tube | 1 | (PER ROOM) |
| balance, spring | 15 | (if l.c. is 30) |
| magnesium ribbon | 4 g | (for every 30) |

You will need to understand the meaning of the labels before you can order correct quantities:

| Label | Meaning | How to determine the quantities you will need |
|---|---|---|
| (PER ROOM) | ... | Simply order the quantity given in the list. (These quantities are independent of the number of students or the number of classes meeting in a given room.) |
| (if l.c. is 30) | (if your largest class is 30 students) | Order proportionately more or less than the listed quantities, as the number of students *in your largest class* is more or less than 30. |
| (for every 30) | (for every 30 students) | Order proportionately more or less than the listed quantities, as the *total number of students* for whom you are ordering is more or less than 30. |

Applying the directions given in the table to the items listed above the table, a teacher having a total of 120 students whose largest class had 40 students would order:

| | | |
|---|---|---|
| | | **1 Geiger counter** |
| 40/30 x 15 spring balances | *or* | 20 spring balances |
| 120/30 x 4 g mag. ribbon | *or* | 16 g magnesium ribbon |

*Where and how to order materials*–Prentice-Hall has assembled a package of equipment especially designed for parts of the IIS Physical Science laboratory program. The contents of this package are those items given in Group #1 of List #1. Send for an IIS catalog for ordering information to Prentice-Hall, Inc., P.O. Box 900, Educational Book Division, Englewood Cliffs, New Jersey 07632.

Any of the numerous scientific supply companies can supply most of the remaining items. Some can be obtained from local sources, such as the materials stock room of your school (where paper clips, chalk, and paper are kept), the hardware store, or the five and dime (variety store). Many schools will already have on hand a good many of these common items.

The investigations where each item is used are given in List #1. *4-3* means *Idea 4, Investigation 3.* You will notice that some items are used frequently while others are used only once. If you are short on funds for materials, check to see which items are used most frequently and therefore are most essential. Items labelled *PER ROOM* are usually demonstration items used only once, and in some instances you may be able to borrow them when the need arises, instead of purchasing them.

The section of this manual covering an individual investigation sometimes gives more detailed information about an item used in that investigation, so if in doubt about a material's specifications, check the individual guide where the item is used.

*Ordering chemicals*–When ordering chemicals, it is not necessary in most cases to order chemicals of high purity designated *Reagent Grade* (R.G.), *Analytical Reagent* (A.R.), or *American Chemical Society* (A.C.S.), unless it specifically calls for it in the list. The less pure chemicals designated *Pure, National Formulary* (N.F.), and *Technical* will suffice in most instances.

# List 1

## GROUP 1

EQUIPMENT–Special  Source: Prentice-Hall, Inc., P.O. Box 900, Ed Book Div., Englewood Cliffs, N.J. 07632. Send for IIS catalog for ordering information.

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| ball set:<br>rubber, 1" dia. white<br>rubber, 2" dia. white<br>rubber, 3" dia. white<br>styrofoam, 3" white<br>plastic, 2" dia. white<br>tennis | 1-1; 1-3; 1-8; 1-10 | 15 | (if l.c. is 30)(1) |
| ball, Ping-Pong | 1-1; 1-2; 1-3; 1-8; 1-10; 5-7 | 15 | (if l.c. is 30) |
| ball, 3" styrofoam with ½" hole drilled through middle | 4-12 | 15 | (if l.c. is 30) |
| board, about 4" square, or 4" in dia.; depression in center that is filled with Silly Putty | 4-7 | 1 | (PER ROOM) |
| bulb, flashlight, 3 volts, 0.35 amp | 5-1; 5-2; 5-4; 5-5; 5-9; 5-10 | 90 | (if l.c. is 30) |
| carpet, 9" square, with rubber back | 5-11 | 1 | (PER ROOM) |
| carpet, 9" sq. without rub. backing | 5-11 | 1 | (PER ROOM) |
| charcoal, granules, No. 6 mesh | 5-9 | 400 grams | (if l.c. is 30) |
| compass, magnetic, marked in degrees; must have reasonably good bearings | 5-4; 5-5; 5-6; 5-9 | 15 | (if l.c. is 30) |
| cube, ml, plastic | 1-7 | 15 | (if l.c. is 30) |
| cube, liter, plastic | 1-7 | 1 | (PER ROOM) |
| cylinder, metal, 2" long, dia. a little less than Silly Putty hole (See "board" above) | 2-1; 3-6; 4-7; 5-7 | 15 | (if l.c. is 30) |
| density set:<br>six blocks 1½ x 1½ x 4 cm (approx)<br>aluminum (No. 1)<br>balsa (No. 2)<br>hardwood (No. 3)<br>iron (No. 4)<br>polyurethane (No. 5)<br>rubber (No. 6)<br>two blocks 1½ x 1½ x 6 cm (approx)<br>aluminum (No. 7)<br>iron (No. 8) | 2-1; 2-2; 5-7<br>(Each of the 8 blocks should be assigned a different number which should be painted on the block; they should all be painted the same color with a paint that adheres well) | 15 | (if l.c. is 30) |
| dowel, 2 feet x ½" | 4-9; 4-10 | 15 | (if l.c. is 30) |
| dowel, 7" x ½" | 4-12 | 15 | (if l.c. is 30) |
| flip cards | 5-10 | 15 | (if l.c. is 30) |

(1) if your largest class is 30 students (proportionately more if your largest class is larger than 30, less if it is smaller).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| hoop, embroidery, supplied with parchment paper | 5-8 | 15 | (if l.c. is 30) |
| magnet, alnico, cylindrical 6" x 3/8" | 5-4; 5-5; 5-6; 5-8 | 15 | (if l.c. is 30) |
| marble set: 15 marbles of one color<br>15 marbles of 2nd color<br>1 marble of a 3rd color | 2-11 | 15 sets | (if l.c. is 30) |
| metal strip, iron 2" x 1/2" x 1/32" | 5-8 | 15 | (if l.c. is 30) |
| microphone kit | 5-9 | 15 | (if l.c. is 30) |
| motor, and solar cell | 3-7 | 1 | (PER ROOM) |
| radioactive sample, 50 microcurie beta emitter | 2-10; 3-7; 3-8 | 15 | (if l.c. is 30) |
| rock specimen with obvious marine fossils | 4-5; 4-7 | 15 | (if l.c. is 30) |
| rod, carbon, 1/8" x 4" long | 5-2 | 30 | (if l.c. is 30) |
| rod, copper, 1/8" x 4" long | 5-2 | 15 | (if l.c. is 30) |
| rod, glass, 1/8" x 4" long | 5-2 | 15 | (if l.c. is 30) |
| rod, iron, 1/8" x 4" long | 5-2 | 15 | (if l.c. is 30) |
| screens, wire, 1/4" mesh, 3 x 3" | 1-6 | 45 | (if l.c. is 30) |
| spike, iron, 6" long x 1/4" | 3-2; 5-5; 5-6; 5-8 | 15 | (if l.c. is 30) |
| spool, wooden thread | 3-1 | 15 | (if l.c. is 30) |
| spring, steel spiral, 1.5 cm dia. 4 cm long | 1-4 | 15 | (if l.c. is 30) |
| stone, to fit into grad'd cylinder | 2-1; 4-4; 5-7 | 15 | (if l.c. is 30) |
| thermostat, simple, 85-100$^{o}$ Celsius | 5-1 | 1 | (PER ROOM) |
| thermostat, automobile radiator | 5-1 | 1 | (PER ROOM) |
| tubing, 6 mm O.S., 12 cm long 135$^{o}$ bend, drawn-out tip | 3-5 | 15 | (if l.c. is 30) |
| tubing, 6 mm O.S., 12 cm long 90$^{o}$ bend | 4-3 | 15 | (if l.c. is 30) |
| washer, metal, 3/4" outside dia. | 1-1; 1-2; 1-5; 1-8 | 45 | (if l.c. is 30) |
| weight, 3 oz fish sinker | 1-4; 5-11 | 15 | (if l.c. is 30) |
| weight, 8 oz fish sinker | 1-4; 3-3; 4-8 | 15 | (if l.c. is 30) |
| wire, copper, not insulated, 1/16" dia. x 4 " long | 4-11 | 15 | (if l.c. is 30) |
| wire, steel, not insulated, 1/16" dia. x 4" long | 4-11 | 15 | (if l.c. is 30) |
| wood, 1" x 5" x 5" (dowel support) with 2 holes: (1) right angle to flat surface & (2) at 66½$^{o}$ | 4-9; 4-10; 4-12 | 15 | (if l.c. is 30) |
| wood, 2" x 2" x 1/8" | 4-7 | 15 | (if l.c. is 30) |
| wood, 6" x 3" x 1" (dimensions are not critical) | 4-4; 5-8 | 15 | (if l.c. is 30) |
| wood, 2 ft x 4" x 1" | 1-10; 3-4 | 15 | (if l.c. is 30) |
| wood, 1/8" x 1" x 12" | 1-6 | 15 | (if l.c. is 30) |
| wood, 1/4" x 2" x 2" | 5-4; 5-5; 5-9 | 30 | (if l.c. is 30) |

## GROUP 2

EQUIPMENT–Common | Possible source: Scientific supply company (any of numerous).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| balance, platform, 500 g capacity | 1-7; 2-1; 2-2; 2-3; 2-5; 3-4; 4-2; 5-2; 5-3 | 15(2) | (if l.c. is 30) |
| balance, spring, 250 g capacity | 3-3; 3-4; 5-7; 5-11 | 15 | (if l.c. is 30) |
| battery pack (to hold 4 flashlight D cells in series) Note that Hickok Teaching Systems supplies this with batteries | 2-8; 3-2; 5-1; 5-2; 5-4; 5-5; 5-6; 5-8; 5-9; 5-10 | 15 | (if l.c. is 30) |
| beaker, Pyrex, 100 ml | 2-5; 3-6; 4-2; 4-3; 4-4; 4-5; 4-6; 5-3; 5-4; 5-11 | 30 | (if l.c. is 30) |
| beaker, plastic, 100 ml | 5-9 | 15 | (if l.c. is 30) |
| beaker, plastic, 250 ml (or glass) | 2-6; 2-7; 2-8; 3-6; 4-6 | 15 | (if l.c. is 30) |
| beaker, plastic, 400 ml (or glass) | 2-3; 4-4; 4-6; 5-7 | 15 | (if l.c. is 30) |
| beaker, Pyrex, 600 ml | 1-7; 4-5; 4-7; 5-1; 5-6 | 15 | (if l.c. is 30) |
| bulb, 40 watts, 115 volts | 4-12; 5-2; 5-4 | 15 | (if l.c. is 30) |
| bulb, 100 watts, 115 volts | 4-2 | 15 | (if l.c. is 30) |
| burner, Bunsen (preferably) or an alcohol burner | 2-4; 2-9; 3-5; 3-7; 4-2; 4-3; 4-5; 4-6; 4-11; 5-1; 5-2; 5-11 | 15 | (if l.c. is 30) |
| cart (or Hall's carriage or toy truck) | 3-4; 5-7 | 15 | (if l.c. is 30) |
| chart, wall, metric system | 1-7 | 1 | (PER ROOM) |
| cheesecloth, 9 inch squares | 4-3 | 15 | (if l.c. is 30) |
| clamp, burette | 1-4; 2-4; 2-9; 3-3; 3-5; 4-2; 4-3; 4-11; 4-12; 5-2; 5-5; 5-6 | 15 | (if l.c. is 30) |
| clock with second hand or metronome | 1-2; 1-4; 1-5; 1-10; 2-8; 3-8 | 1 | (PER ROOM) |
| cloth, cotton, 5 inches square | 2-10 | 15 | (if l.c. is 30) |
| cloth, silk, 5 inches square | 2-10 | 15 | (if l.c. is 30) |
| cloth, wool, 5 inches square | 2-10 | 15 | (if l.c. is 30) |
| cloud chamber with radioactive source | 2-10 | 1 | (PER ROOM) |
| cork, about ½" diameter | 4-11 | 15 | (if l.c. is 30) |
| cylinder, graduated, 100 ml | 1-7; 2-1; 2-2; 2-6; 2-7; 3-6; 4-4; 4-5; 4-6; 5-3; 5-7 | 30 | (if l.c. is 30) |
| earphones | 5-8; 5-9 | 15 | (if l.c. is 30) |
| electrodes, stainless steel | 2-8 | 30 | (if l.c. is 30) |
| electroscope | 2-10 | 15 | (if l.c. is 30) |
| eyedropper, about 3" glass section | 1-2; 1-7; 2-10 | 15 | (if l.c. is 30) |

(2)preferably 15 balances, although fewer can be made to do

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| flask, Erlenmeyer, Pyrex, 250 ml | 2-5; 4-3 | 15 | (if l.c. is 30) |
| funnel, glass, 8 cm diameter | 2-5; 5-3; 5-7 | 15 | (if l.c. is 30) |
| gauze, wire, asbestos center | 3-7; 4-2; 4-3; 4-5; 4-6; 4-11; 5-1 | 15 | (if l.c. is 30) |
| Geiger tube | 2-10; 3-8 | 1 | (PER ROOM) |
| power supply for Geiger tube | | 1 | (PER ROOM) |
| audioamplifier | | 1 | (PER ROOM) |
| speaker | | 1 | (PER ROOM) |
| grating, diffraction, transmission | 4-11 | 15 | (if l.c. is 30) |
| induction coil (spark coil) | 4-11 | 1 | (PER ROOM) |
| jar, clear plastic, wide mouth, 1 qt size, watertight lid | 1-2; 2-6; 3-6; 4-3 | 15 | (if l.c. is 30) |
| jar, clear plastic, small mouth, 1 pt size, watertight lid | 1-2 | 15 | (if l.c. is 30) |
| magnifying glass | 4-5; 5-10 | 15 | (if l.c. is 30) |
| metal strip, 4" x 1/2" x 1/32" | | | |
| aluminum (optional) | 5-4 | 15 | (if l.c. is 30) |
| copper (required) | 5-4; 5-10 | 30 | (if l.c. is 30) |
| lead (optional) | 5-4 | 15 | (if l.c. is 30) |
| zinc (optional) | 5-4 | 15 | (if l.c. is 30) |
| meter stick, rigid hardwood | 1-7; 1-8; 2-11; 3-3; 3-4; 3-8; 4-2; 4-9; 4-10 | 30 | (if l.c. is 30) |
| Petri dish, plastic | 3-6; 4-5 | 15 | (if l.c. is 30) |
| prism, glass | 4-11 | 15 | (if l.c. is 30) |
| pulley, single, about 3" dia. | 3-3 | 15 | (if l.c. is 30) |
| radiometer | 3-2 | 4 | (PER ROOM) |
| ring, iron, about 3" dia. | 4-2; 4-3; 4-5; 4-6; 5-1; 5-3 | 15 | (if l.c. is 30) |
| ring stand | 1-4; 3-3; 4-2; 4-3; 4-5; 4-6; 4-11; 4-12; 5-1; 5-3; 5-6 | 15 | (if l.c. is 30) |
| rod, stirring, glass, about 6" x 3/16" | 4-5; 4-6; 5-3; 5-4; 5-5; 5-11 | 15 | (if l.c. is 30) |
| sand (does not need to be of high purity) (Listed also on *common supply* list—see Group 8) | 4-2 | 20 lb | (if l.c. is 30) |
| scale, bathroom, calibrated in kilograms(3) | 1-7 | 1 | (PER ROOM) |
| socket, flashlight bulb | 5-1; 5-2; 5-4; 5-5; 5-9; 5-10 | 90 | (if l.c. is 30) |
| spectrum tubes, gas, at least two of the following four: H Ne He A | 4-11 | 2 to 4 tubes | (PER ROOM) |
| spring, Slinky | 4-8 | 15 | (if l.c. is 30) |
| stopper, rubber, one hole, No. 2 | 3-5 | 15 | (if l.c. is 30) |
| stopper, rubber, solid, No. 2 | 2-3 | 15 | (if l.c. is 30) |
| stopper, rubber, solid, No. 5½ | 2-6 | 15 | (if l.c. is 30) |
| stopper, rubber, solid, No. 6 | 2-5 | 15 | (if l.c. is 30) |
| stopper, rubber, one hole, No. 6 | 4-3 | 15 | (if l.c. is 30) |

(3)May be available from IIS Biology teacher

GROUP 2 cont.

EQUIPMENT–Common    Possible source: Scientific supply company (any of numerous).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| strip, acetate, 12" x 1" x 1/16" | 2-10 | 30 | (if l.c. is 30) |
| strip, vinyl, 12" x 1" x 1/16" | 2-10 | 30 | (if l.c. is 30) |
| switch, knife, electrical | 5-1; 5-8 | 15 | (if l.c. is 30) |
| thermometer, standard laboratory -10 to 110° Celsius | 3-6; 4-2; 4-3; 5-1 | 15 | (if l.c. is 30) |
| transformer, 115 volts to 10 volts 50 to 60 cycles | 5-8 | 1 | (PER ROOM) |
| tube, test, Pyrex, 18 x 150 mm | 2-3; 2-9; 2-10; 3-5; 4-2; 4-6; 5-6 | 15 | (if l.c. is 30) |
| tube, culture, Pyrex, 13 x 100 mm | 2-5; 3-5 | 15 | (if l.c. is 30) |
| tubing, glass, 6 mm outside dia. | 3-5; 4-3 | 40 feet | (if l.c. is 30) |
| vial, capacity of 5 ml (about 2 drams) | 3-6 | 15 | (if l.c. is 30) |
| watch glass, Pyrex, 90 mm dia. approx | 3-6; 5-11 | 15 | (if l.c. is 30) |
| wire, copper, enameled, B&S 24 (780 feet per pound) | 3-2; 5-4; 5-5; 5-9; 5-10 | 1000 feet | (if l.c. is 30) |
| wires, clip leads, about 14" long, alligator clip ends | 2-8; 3-2; 5-1; 5-2; 5-4; 5-5; 5-6; 5-8; 5-9; 5-10 | 45 | (if l.c. is 30) |

## GROUP 3

EQUIPMENT–Common    Possible source: Miscellaneous.

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| bags, paper, heavy duty lunch | 1-1 | 30 | (if l.c. is 30) |
| cardboard, such as is used for scratch pad backing, 2 inch squares | 3-8 | 32 pieces | (PER ROOM) |
| cardboard, disc, 18" diameter | 4-2 | 1 | (PER ROOM) |
| compasses, geometry(4) | 3-5; 5-6 | 15 | (if l.c. is 30) |
| cup, metal, 8 oz (tin can will do) | 4-3 | 15 | (if l.c. is 30) |
| dominos, set of | 3-7 | 15 | (if l.c. is 30) |
| pan, pie, aluminum, disposable 6" to 8" diameter | 4-2; 5-3; 5-5 | 30 | (if l.c. is 30) |
| protractor(4) | 4-2; 4-12 | 15 | (if l.c. is 30) |
| razor blade, single edge | 4-5 | 15 | (if l.c. is 30) |
| ruler, 12" metric, with ridge running down middle (to serve as a marble track) | numerous places | 30 | (if l.c. is 30) |
| scissors(5) | 3-5; 5-6 | 15 | (if l.c. is 30) |
| turntable, lazy Susan | 4-2 | 1 | (PER ROOM) |



(4) Borrow from your math department
(5) Try your school office stockroom or art department

## GROUP 4

EQUIPMENT–Common    Possible source: Hardware store (See SUPPLY list, also).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| bolts, 10-24, 3/8" long | 1-6 | 90 | (if l.c. is 30) |
| bolts, 10-32, ½" long | 1-6 | 90 | (if l.c. is 30) |
| nuts, hexagonal, 10-24(6) | 1-6 | 90 | (if l.c. is 30) |
| nuts, hexagonal, 10-32(6) | 1-6 | 90 | (if l.c. is 30) |
| flashlight, common 2 cell | 2-10; 4-11 | 15 | (if l.c. is 30) |
| nail, 5" long | 3-7 | 15 | (if l.c. is 30) |
| socket with 6 foot cord and plug (for 40 and 100 watt bulbs) | 4-2; 4-12; 5-2; 5-4 | 15 | (if l.c. is 30) |
| wire, lampcord, 10 feet long | 5-8; 5-9 | 15 | (if l.c. is 30) |

(6)It is suggested that the one size nut be steel, the other size aluminum so that a magnet can be used to sort them easily

## GROUP 5

SUPPLIES–Common    Possible source: Hardware store (See EQUIPMENT list, also).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| cement powder | 5-3 | 600 g | (for every 30) |
| gravel, coarse (6 mesh) | 4-5 | 8 pounds | (for every 30) |
| gravel, fine (12 mesh) | 1-2; 4-5; 5-3 | 10 pounds | (for every 30) |
| plaster, patching | 4-4 | 5 pounds | (for every 30) |
| sandpaper, fine grit, 8½ x 11" sheets | 3-2; 5-4; 5-5; 5-6; 5-8; 5-9; 5-10 | 20 sheets | (for every 30) |
| wood, dowel, ½" dia. x 4" | 5-11 | 15 pieces | (for every 30) |

## GROUP 6

SUPPLIES–Common    Possible source: Five and dime.

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| balloon, round, to fit over mouth of common size test tube (18 x 150mm) | 2-4; 4-2 | 30 | (for every 30) |
| candle, slice of, 3/4" dia. x 1/4", wick removed | 3-1 | 15 pieces | (for every 30) |
| cup, paper, 1 oz | 4-4; 5-3 | 45 | (for every 30) |
| cup, paper, 8 oz | 5-3; 5-7 | 30 | (for every 30) |
| nailpolish (to demonstrate flammability) | 5-11 | 2 ounces | (for every 30) |
| nail polish remover | 5-11 | 2 ounces | (for every 30) |
| paper, tissue, sheets 8½ x 11" | 3-6 | 5 sheets | (for every 30) |
| pin, straight, common | 3-5; 4-5 | 15 | (for every 30) |
| string, cotton | numerous places | 400 feet | (for every 30) |
| thread | 1-2; 2-1 | 120 inches | (for every 30) |

## GROUP 7

SUPPLIES–Common    Possible source: The supply stock room of your school.

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| cardboard, manila folder | 3-5; 5-3; 5-6; 5-7 | 8 folders | (for every 30) |
| chalk | 2-11; 3-7 | 8 small pieces | (for every 30) |
| paper, white, unruled, 8½ x 11" | 3-5; 4-8; 4-10; 4-11; 5-7 | 120 sheets | (for every 30) |
| paper, black, 8½ x 11" | 4-11 | 3 sheets | (for every 30) |
| paper towels | numerous places | 300 towels | (for every 30) |
| paper clip, standard size | numerous places | 200 clips | (for every 30) |
| paper clip, larger, 2" size | 2-1; 3-3 | 90 clips | (for every 30) |
| rubber band, about 3" length | 3-1; 5-8; 5-9 | 45 | (for every 30) |
| stick mixer (tongue depressor or ice cream stick)(7) | 3-5; 4-4; 5-3; 5-11 | 60 | (for every 30) |
| straw, drinking(8) | 3-5 | 15 | (for every 30) |
| tape, masking, ½" width | numerous places | 200 feet | (for every 30) |
| wood, 4" x 2" x ¾" (dimensions are not critical)(9) | 5-3 | 30 pieces | (for every 30) |

(7)Try cafeteria or nurse
(8)Try cafeteria
(9)Try shop or maintenance

## GROUP 8

SUPPLIES–Common    Source: Scientific supply company (any of numerous).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| Batteries, flashlight D cells (Note: Do not order these if you buy battery packs with batteries) | 2-8; 3-2; 5-1; 5-2; 5-4; 5-5; 5-8; 5-9; 5-10 | 60 cells | (PER ROOM) |
| boiling chips | 3-5; 4-3 | 100 | (for every 30) |
| cotton, absorbent | 5-11 | 1/5 lb | (for every 30) |
| filter paper, 4" or 5", med. speed | 5-3 | 15 circles | (for every 30) |
| jar, glass, with screw cap, 30 ml (to be fractured by freezing water in it) | 4-4 | 15 | (for every 30) |
| matches | numerous places | 200 | (for every 30) |
| rod, glass, stirring 6" x 3/16" | 5-3 (where it is destroyed) | 8 | (for every 30) |
| rod, carbon, 1/8" x 4" | 4-11 | 15 | (for every 30) |
| splint, wooden | 2-8; 2-9; 4-3 | 100 | (for every 30) |
| tube, culture, Pyrex 13 x 100 mm | 2-9 (where it is consumed) | 15 | (for every 30) |
| tube, test, Pyrex, 18 x 150 mm | 2-4 (where it is consumed) | 15 | (for every 30) |

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| CHEMICALS | | | |
| alcohol, ethyl, denatured 95% | 2-2; 3-6 and numerous other places if alcohol burner is used | 1 liter(10) | (for every 30) |
| ammonium chloride, granular | 3-6 | 150 g | (for every 30) |
| ammonium hydroxide, concentrated | 5-11 | 225 g | (for every 30) |
| calcite (calcium carbonate) | 4-4 | 150 g | (for every 30) |
| calcium chloride, granular, anhydrous | 3-6 | 150 g | (for every 30) |
| copper sulfate, $CuSO_4 \cdot 5H_20$ | 4-5 | 75 g | (for every 30) |
| formaldehyde | 5-3 | 375 ml | (for every 30) |
| hydrochloric acid, concentrated, reagent grade | 2-7; 5-3 | 250 ml | (for every 30) |
| magnesium ribbon | 2-7; 5-4 | 4 g | (for every 30) |
| magnesium sulfate, $MgS0_4 \cdot 7H_20$ | 3-6 | 150 g | (for every 30) |
| mercuric oxide, technical | 2-9 | 75 g | (for every 30) |
| nickel sulfate, $NiSO_4 \cdot 6H_2O$ | 4-6 | 270 g | (for every 30) |
| phenolphthalein, solid (*or* 0.5% solution) | 2-5 | 1 g solid (or 1 liter liquid) | (for every 30) (for every 30) |
| phenyl salicylate | 4-6 | 300 g | (for every 30) |
| potassium sulfate | 4-6 | 150 g | (for every 30) |
| sand (does not have to be of high purity; sand is also listed in Group 2) | 4-4; 4-5; 5-3 | 6 pounds | (for every 30) |
| sodium carbonate, granular | 2-5; 2-8; 3-6 | 750 g | (for every 30) |
| sodium chloride, rock salt | 2-6 | 5 pounds | (for every 30) |
| sodium chloride, technical | 3-6; 4-4; 5-4 | 4 pounds | (for every 30) |
| sodium peroxide, $Na_2O_2$ | 2-9 | 20 g | (for every 30) |
| sodium silicate, solid | 4-6 | 170 g | (for every 30) |
| sulfur, powdered (flowers of sulfur) | 2-4 | 300 g | (for every 30) |
| sulfuric acid, concentrated, reagent grade | 2-9 | 25 ml | (for every 30) |
| urea | 5-3 | 105 g | (for every 30) |

(10)More than 1 liter, if alcohol burners are used

## GROUP 9

SUPPLIES—Common    Possible source: Miscellaneous (mostly, the food store).

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| beans, dried (baby lima, pinto, etc.) | 4-4 | 800 ml | (for every 30) |
| chlorine bleach | 5-11 | 8 ounces | (for every 30) |
| Karo syrup | 2-2 | 1¼ qts | (for every 30) |
| lemon juice | 4-4 | 11 fl. oz | (for every 30) |
| popcorn | 2-6 | 4 qts | (for every 30) |
| Puffed Rice | 2-6 | 4 qts | (for every 30) |
| Dry Ice | 2-10; 4-2 | small quantity | |
| ice | 2-3; 4-2; 4-3; 4-4; 4-7; 5-2 | 1 kg, average | (for every 30) |
| milk cartons, empty, 1 qt size | 4-5 | 15 cartons | (for every 30) |

## GROUP 10

SUPPLIES—Special    Source: Prentice-Hall, Inc., P.O. Box 900, Ed. Book Div., Englewood Cliffs, N.J. 07632. Send for an IIS catalog for ordering information.

| ITEM | WHERE USED | QUANTITY | |
|---|---|---|---|
| Atomikit: Each kit has the following components: film, 4" x 5" wrapped in a light-tight, flexible plastic envelope; film developer; film fixer; syringe, for injecting developer and fixer into the plastic envelope while in a lighted room | 3-7 | 15 kits | (for every 30) Note: only 15 syringes need be bought PER ROOM |
| Wire, fuse, 1 amp (must melt when 4 of the flashlight bulbs are put in parallel—See equipment list and section of this Guide for Idea 5, Inv. 5) | 5-5 | 15 inches | (for every 30) |

# List 2

## AN ALPHABETICAL LISTING OF ALL LABORATORY MATERIALS GIVEN IN LIST 1

List # 1 categorized laboratory materials by source, in order to make it easier for the teacher to order materials. This alphabetical list is designed to help teachers locate individual items in List # 1 when occasionally the need to do so arises.

| ITEM | WHERE FOUND IN LIST 1 |
|---|---|
| acetate strip | Group 2 under "strip, acetate" |
| alcohol | Group 8 |
| aluminum strip | Group 2 under "metal strip" |
| ammonium chloride | Group 8 under "CHEMICALS" |
| ammonium hydroxide | Group 8 under "CHEMICALS" |
| Atomikit | Group 10 |
| bags, paper | Group 3 |
| balance, platform | Group 2 |
| balance, spring | Group 2 |
| ball, styrofoam | Group 1 |
| ball set | Group 1 |
| balloon | Group 6 |
| base, for dowel | Group 1 under "wood . . . " |
| bathroom scale | Group 2 under "scale, bathroom" |
| batteries | Group 8 |
| battery pack | Group 2 |
| beakers | Group 2 |
| beans, dried | Group 9 |
| bleach, chlorine | Group 9 |
| blocks | Group 1 under "density set" |
| board, Silly Putty | Group 1 |
| board | (Look under "wood" in this list) |
| boiling chips | Group 8 |
| bolts | Group 4 |
| bottle | (See "jar" in this list) |
| bulb, flashlight | Group 1 |
| bulb, 40 & 100 watt | Group 2 |
| burner | Group 2 |
| burette clamp | Group 2 under "clamp, burette" |
| calcite (calcium carbonate) | Group 8 under "CHEMICALS" |
| calcium chloride | Group 8 under "CHEMICALS" |
| candle | Group 6 |
| carbon rod | Group 1 under "rod, carbon" |
| cardboard, disc | Group 3 |
| cardboard, scratch pad backing | Group 3 |
| cardboard, manila folder | Group 7 |
| carpet | Group 1 |
| cart | Group 2 |
| cement powder | Group 5 |
| chalk | Group 7 |
| charcoal | Group 1 |
| chart, wall, metric | Group 2 |
| cheesecloth | Group 2 |
| chemicals | Group 8 |

| ITEM | WHERE FOUND IN LIST 1 |
|---|---|
| chlorine bleach | Group 9 |
| clamp, burette | Group 2 |
| clip leads | Group 2 under "wire, clip leads" |
| clock | Group 2 |
| cloth: cotton, wool, silk | Group 2 |
| cloud chamber | Group 2 |
| compasses, geometry | Group 3 |
| compass, magnetic | Group 1 |
| concrete | Group 5 under "cement" |
| copper sulfate, $CuSO_4 \cdot H_2O$ | Group 8 under "CHEMICALS" |
| copper rod | Group 1 under "rod, copper" |
| copper strip | Group 2 under "metal strip" |
| copper wire | Groups 1 & 2 under "wire, copper" |
| cork | Group 2 |
| cotton | Group 8 |
| cotton cloth | Group 2 under "cloth, cotton" |
| cube, plastic | Group 1 |
| culture tube | Groups 2 & 8 under "tube, culture" |
| cup, paper | Group 6 |
| cup, metal | Group 3 |
| cylinder, graduated | Group 2 |
| cylinder, metal | Group 1 |
| density set | Group 1 |
| developer, film | Group 10 under "Atomikit" |
| diffraction grating | Group 2 under "grating" |
| dominos | Group 3 |
| dowel, 2 feet x ½" | Group 1 |
| dowel, 7" x ½" | Group 1 |
| dowel, 4" x ½" | Group 5 under "wood, dowel" |
| dowel support | Group 1 under "wood . . . " |
| Dry Ice | Group 9 |
| earphones | Group 2 |
| electrodes | Group 2 |
| electroscope | Group 2 |
| Erlenmeyer flask | Group 2 under "flask, Erlenmeyer" |
| eyedropper | Group 2 |
| film | Group 10 under "Atomikit" |
| filter paper | Group 8 |
| fish sinker | Group 1 under "weight" |
| fixer, film | Group 10 under "Atomikit" |
| flask, Erlenmeyer | Group 2 |
| flashlight, common | Group 4 |
| flashlight batteries | Group 8 under "batteries" |
| flashlight bulb socket | Group 2 under "socket" |
| flashlight bulb | Group 1 under "bulb, flashlight" |
| flip cards | Group 1 |
| folder | Group 7 under "cardboard, manila folder" |
| formaldehyde | Group 8 |
| fossil rock | Group 1 under "rock specimen" |
| funnel | Group 2 |
| fuse wire | Group 10 under "wire, fuse" |
| gauze, wire | Group 2 |

| ITEM | WHERE FOUND IN LIST 1 |
|---|---|
| Geiger tube<br>power supply<br>audioamplifier<br>speaker | Group 2 |
| glass rod | Group 1 under "rod, glass" |
| glass tubing | Group 2 under "tubing, glass" |
| graduated cylinder | Group 2 under "cylinder" |
| graph paper | Group 7 under "paper, graph" |
| grating, diffraction | Group 2 |
| gravel | Group 5 |
| hoop, embroidery | Group 1 |
| hydrochloric acid | Group 8 under "CHEMICALS" |
| ice | Group 9 |
| ice cream stick | Group 7 under "stick mixer" |
| induction coil | Group 2 |
| iron ring | Group 2 under "ring, iron" |
| iron rod | Group 1 under "rod, iron" |
| iron strip | Group 1 under "metal strip" |
| jar, clear plastic | Group 2 |
| jar, glass with cap | Group 8 |
| Karo syrup | Group 9 |
| knife, switch | Group 2 under "switch, knife" |
| lampcord | Group 4 under "wire" |
| lead strip | Group 2 under "metal strip" |
| lemon juice | Group 9 |
| lightbulb, flashlight | Group 1 under "bulb, flashlight" |
| lightbulb, 40 or 100 watts | Group 2 under "bulb" |
| magnesium ribbon | Group 8 under "CHEMICALS" |
| magnesium sulfate, $MgSO_4 \cdot H_2O$ | Group 8 under "CHEMICALS" |
| magnet | Group 1 |
| magnifying glass | Group 2 |
| manila folder | Group 7 under "cardboard" |
| marble set | Group 1 |
| masking tape | Group 7 under "tape, masking" |
| matches | Group 8 |
| medicine dropper | Group 2 under "eyedropper" |
| mercuric oxide | Group 8 under "CHEMICALS" |
| metal cup | Group 3 under "cup, metal" |
| metal strips, 4" x ½" x 1/32" | Group 2 |
| metal strip, iron | Group 1 |
| meter stick | Group 2 |
| metronome | Group 2 under "clock" |
| microphone kit | Group 1 |
| milk cartons | Group 9 |
| motor & solar cell | Group 1 |
| nail, 5" long | Group 4 |
| nail (spike) | Group 1 under "spike" |
| nail polish | Group 6 |
| nail polish remover | Group 6 |
| nickel sulfate, $NiSO_4 \cdot 6H_2O$ | Group 8 under "CHEMICALS" |
| nuts | Group 4 |
| pan, pie, aluminum | Group 3 |
| paper bags | Group 3 under "bags" |
| paper clip | Group 7 |

| ITEM | WHERE FOUND IN LIST 1 |
|---|---|
| paper cup | Group 6 under "cup, paper" |
| paper, tissue | Group 6 |
| paper towels | Group 7 |
| paper, white | Group 7 |
| paper, black | Group 7 |
| patching plaster | Group 5 under "plaster" |
| Petri dish | Group 2 |
| phenolphthalein | Group 8 under "CHEMICALS" |
| phenyl salicylate | Group 8 under "CHEMICALS" |
| Ping-Pong ball | Group 1 under "ball set" |
| pin, straight | Group 6 |
| plaster, patching | Group 5 |
| plastic strip | Group 2 under "strip, plastic" |
| platform balance | Group 2 under "balance" |
| popcorn | Group 9 |
| potassium sulfate | Group 8 under "CHEMICALS" |
| prism, glass | Group 2 |
| protractor | Group 3 |
| Puffed Rice | Group 9 |
| pulley, single | Group 2 |
| radioactive sample | Group 1 |
| radiometer | Group 2 |
| razor blade | Group 3 |
| ring, iron | Group 2 |
| ring stand | Group 2 |
| rock specimen | Group 1 |
| rod, carbon | Groups 1 & 8 |
| rod, copper | Group 1 |
| rod, glass 1/8" x 4" long | Group 1 |
| rod, glass, stirring | Groups 2 & 8 |
| rod, iron | Group 1 |
| rubber band | Group 7 |
| rubber stopper | Group 2 under "stopper" |
| rug | Group 1 under "carpet" |
| ruler, homemade | Group 1 under "wood . . . " |
| ruler, 12 " metric | Group 3 |
| sand | Groups 2 & 8 |
| sandpaper | Group 5 |
| scale, bathroom | Group 2 |
| scissors | Group 3 |
| screens, wire | Group 1 |
| screws | Group 4 under "bolts" |
| Silly Putty | Group 1 under "board" |
| silk cloth | Group 2 under "cloth, silk" |
| sinker, fishing | Group 1 under "weight" |
| Slinky | Group 2 under "spring" |
| socket, flashlight bulb | Group 2 |
| socket with 6 ft cord and plug | Group 4 |
| sodium compounds | Group 8 under "CHEMICALS" |
| solar cell | Group 1 under "motor . . . " |
| spark coil | Group 2 under "induction coil" |
| spectrum tubes | Group 2 |
| spike, iron | Group 1 |
| splint, wooden | Group 8 |
| spool | Group 1 |

| ITEM | WHERE FOUND IN LIST 1 |
|---|---|
| spring balance | Group 2 under "balance" |
| spring, Slinky | Group 2 |
| spring, steel spiral | Group 1 |
| steel wire | Group 1 under "wire, steel" |
| stick mixer | Group 7 |
| stone | Group 1 |
| stopper, rubber | Group 2 |
| stirring rod | Groups 2 & 8 under "rod . . . " |
| straw, drinking | Group 7 |
| string, cotton | Group 6 |
| strip, plastic | Group 2 |
| styrofoam sphere | Group 1 under "ball, styrofoam" |
| sulfur | Group 8 under "CHEMICALS" |
| sulfuric acid | Group 8 under "CHEMICALS" |
| switch, knife | Group 2 |
| switch, thermostatic | Group 1 |
| syringe | Group 10 under "Atomikit" |
| syrup, Karo | Group 9 under "Karo" |
| tape, masking | Group 7 |
| tennis ball | Group 1 under "ball set" |
| test tube | Groups 2 & 8 under "tube, test" |
| thermometer | Group 2 |
| thermostat, auto | Group 1 |
| thermostatic switch | Group 1 under "switch" |
| thread | Group 6 |
| tin can | Group 3 under "cup, metal" |
| tissue paper | Group 6 under "paper, tissue" |
| tongue depressor | Group 7 under "stick mixer" |
| towels, paper | Group 7 under "paper towels" |
| transformer | Group 2 |
| truck | Group 2 under "cart" |
| tube, culture & test | Groups 2 & 8 |
| tubing, glass | Group 2 |
| vial | Group 2 |
| vinyl strip | Group 2 under "strip, vinyl" |
| urea | Group 8 under "CHEMICALS" |
| wall chart, metric | Group 2 under "chart, wall" |
| washer, metal | Group 1 |
| watch glass | Group 2 |
| weight | Group 1 |
| wire, clip leads | Group 2 |
| wire, copper, 1/16" dia. x 4" long | Group 1 |
| wire, enameled | Group 2 |
| wire, fuse | Group 10 |
| wire gauze | Group 2 under "gauze, wire" |
| wire screens | Group 1 under "screens, wire" |
| wire, lampcord | Group 4 |
| wire, steel, 1/16" dia. x 4" long | Group 1 |
| wire with light socket and plug | Group 4 under "socket" |
| wood, various pieces | Groups 1 & 7 |
| wood, dowel | Groups 1 & 5 |
| wooden splint | Group 8 under "splint" |
| wool cloth | Group 2 under "cloth, wool" |
| zinc strip | Group 2 under "metal strip" |

## MULTI-MEDIA AIDS (AUDIO-VISUAL AIDS)

There are four categories of multi-media aids:

I. 16 mm films (motion pictures)

II. 8 mm filmloops (regular and Super 8)

III. 8 mm filmstrips

IV. Overhead projector transparencies

Individual titles of multi-media aids are grouped into these categories in the lists which follow. In each category, titles are given in order, starting with Idea 1 and ending with Idea 5. *2-3* is an abbreviation for *Idea 2, Investigation 3.*

Some distributors of multi-media aids do not assign catalog numbers to their titles and for a few titles it wasn't possible to obtain catalog numbers. These titles are marked (*) in the place where normally the catalog number would be given. When ordering these, simply give the titles. In all other cases it is suggested that both title and catalog number be given.

A list of names and addresses of the distributors is given at the end of the title lists.

Some of the makers of multi-media aids sell but do not rent their products. If you are interested in renting, it is suggested that you write to the makers and ask them what agencies rent their films.

## 16 MM FILMS

| | | | | FILM SOURCE AND CATALOG NUMBER | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Where Used | Film Title | Color or B&W | Time | Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
| 1-1 | Science Study Skills | either | 11 min. | | | 1594 | | | |
| 1-2 | Introduction to Physics | either | 11 min. | | | 365 | | | |
| 1-3 | The Scientific Method | color | 12 min. | | | | 703 | | |
| 1-5 | What Is Science (2nd ed.) | either | 11 min. | | | 1627 | | | |
| 1-5 | Scientific Method in Action | color | 19 min. | | | | | | I.F.B.: 21FB240 |
| 1-6 | Using the Scientific Method | either | 11 min. | | | 618 | | | |
| 1-7 | Measurement in Physical Science | either | 13½ min. | | | 1516 | | | |
| 1-7 | Metric System | either | 11 min. | | | 1090 | | | |
| 1-9 | Introducing Graphs | B&W<br>color | 11 min. | | | | | 611994<br>611995 | |
| 1-9 | Language of Graphs | either | 13½ min. | | | 190 | | | |
| 1-10 | Galileo | either | 13½ min. | | | 1172 | | | |
| 1-11 | Aristotle & Scientific Method | either | 13½ min. | | | 1169 | | | |
| 2-3 | Solids, Liquids, and Gases | B&W<br>color | 8 min. | | | | | 401840<br>401843 | |
| 2-3 | Plasma: the 4th State of Matter | color | 10 min. | | 16-281 | | | | |
| 2-4 | Sulfur and Its Compounds | either | 13½ min. | | | 1436 | | | |
| 2-4 | Sulfur and Hydrogen Sulfide | either | 21 min. | | | 1366 | | | |
| 2-5 | Laws of Conservation of Energy and Matter | either | 8 min. | | | 911 | | | |
| 2-5 | Combustion: an Introduction to Chemical Change | | 16 min. | | 16-217 | | | | |

16 MM FILMS (cont)

| Where Used | Film Title | Color or B&W | Time | FILM SOURCE AND CATALOG NUMBER: Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|
| 2-6 | Explaining Matter: Molecules in Motion | either | 11 min. | | | | 1746 | | |
| 2-6 | Evidence for Molecules & Atoms | either | 19 min. | | | | 1886 | | |
| 2-6 | Molecular Theory of Matter | either | 11 min. | | | | 2227 | | |
| 2-7 | Definite and Multiple Proportions | B&W | 30 min. | | | | | | Modern: 0110 |
| 2-8 | Oxygen | either | 11 min. | | | 206 | | | |
| 2-8 | Electrochemical Reactions | either | 13½ min. | | | 1411 | | | |
| 2-9 | Fire and Oxidation | either | 11 min. | | | 1518 | | | |
| 2-9 | The Elements: Building Blocks | . . . | . . . | | | | | | N.E.T.: (*) |
| 2-9 | The Elements: from Alchemy to Chemistry | . . . | 29 min. | | | | | | N.E.T.: (*) |
| 2-10 | Atomic Radiation | B&W | 13 min. | | | | 655 | | |
| 2-10 | Electrostatics (2nd ed.) | B&W | 11 min. | | | | 464 | | |
| 2-11 | Exploring the Atomic Nucleus | either | 13½ min. | | | 1711 | | | |
| 2-11 | Synchrotron | color | 14½ min. | (*) | | | | | |
| 2-11 | A Is For Atom (rev. ed.) | color | 15 min. | (*) | | | | | |
| 2-11 | Atom Smashers (rev. ed.) | color | 18 min. | (*) | | | | | |
| 2-11 | Strange Case of the Cosmic Rays | color | 60 min. | | | | | | Bell Telephone (*) |

16 MM FILMS (cont)

| Where Used | Film Title | Color or B&W | Time | FILM SOURCE AND CATALOG NUMBER: Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|
| 3-1 | Laws of Motion | color | 13 min. | | | | 756 | | |
| 3-2 | Energy from the Sun | B&W<br>color | 16½ min. | | | | 653207<br>653307 | | |
| 3-2 | Waves and Energy | B&W<br>color | 11 min. | | | | 1875<br>1874 | | |
| 3-3 | Pulleys and Work | color | 14½ min. | | 16-262 | | | | |
| 3-3 | Simple Machines: Levers | either | 5½ min. | | | 751 | | | |
| 3-3 | Simple Machines: Pulleys | color | 5½ min. | | | 752 | | | |
| 3-4 | Simple Machines | B&W | 11 min. | | | | 251 | | |
| 3-4 | Simple Machines: Work and Mechanical Advantage | color | 13½ min. | | | 1490 | | | |
| 3-5 | The ABC of the Automobile Engine | color | 18 min. | | | | | | General Motors: (*) |
| 3-6 | Fire Science | either | 15 min. | | | | | | Churchill: (*) |
| 3-6 | Fuels: Their Nature & Use | B&W | 11 min. | | | | 1609 | | |
| 3-6 | Heat: Its Nature and Transfer | B&W | 11 min. | | | | 1608 | | |
| 3-7 | Basic Principles of Power Reactors | color | 8½ min. | (*) | | | | | |
| 3-7 | Controlling Atomic Energy | color | 13 min. | (*) | | | | | |
| 3-7 | Introducing Atoms and Nuclear Energy | either | 11 min. | (*) | | | | | |

16 MM FILMS (cont)

| Where Used | Film Title | Color or B&W | Time | FILM SOURCE AND CATALOG NUMBER: Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|
| 3-8 | The Mighty Atom | color | 27 min. | (*) | | | | | |
| 3-8 | Living with Radiation | color | 38 min. | (*) | | | | | |
| 3-8 | Living with the Atom | color | 18 min. | (*) | | | | | |
| 3-8 | Radiation and the Population | color | 29 min. | (*) | | | | | |
| 3-9 | The Atom and Eve | color | 15 min. | (*) | | | | | |
| 3-9 | Atomic Power Production | color | 14 min. | (*) | | | | | |
| 3-9 | Snapshot | color | 19 min. | (*) | | | | | |
| 3-9 | Tomorrow's Power–Today | color | 5½ min. | (*) | | | | | |
| 4-1 | The Earth: Changes in Its Surface | color | 11 min. | (*) | | 1277 | | | |
| 4-1 | The Great Weather Mystery | B&W | 9 min. | | | | | 618064 | |
| 4-1 | How Solid Is Rock? | B&W<br>color | 22 min. | | | | 2584<br>2585 | | |
| 4-1 | The Inconstant Air | B&W<br>color | 27 min. | | | | | 681104<br>681117 | |
| 4-2 | Air Pollution and Cars | B&W | 16½ min. | | | | | | General Motors: (*) |
| 4-2 | Atmosphere and Its Circulation | B&W | 11 min. | | | | 237 | | |
| 4-2 | The Earth: Its Atmosphere | B&W | 11 min. | | | 1298 | | | |
| 4-2 | The First Mile Up | B&W | 28 min. | | | | | 672320 | |
| 4-2 | Unchained Goddess | color | 60 min. | | | | | | Bell Telephone: (*) |
| 4-2 | What Makes the Wind Blow? | color | 16 min. | | | | 80740 | | |

16 MM FILMS (cont)

| Where Used | Film Title | Color or B&W | Time | Film Source and Catalog Number: Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|
| 4-3 | The Water Cycle | B&W | 11 min. | | | | 366 | | |
| 4-3 | Water for the Community | either | 11 min. | | | 1152 | | | |
| 4-3 | What Makes Clouds? | B&W<br>color | 19 min. | | | | 2252<br>2251 | | |
| 4-3 | Working Water | color | 14 min. | | 16-394 | | | | |
| 4-4 | Erosion | color | 10½ min. | | 16-252 | | | | |
| 4-4 | Erosion–Leveling the Land | B&W<br>color | 14 min. | | | | 2195<br>2194 | | |
| 4-5 | The Deep Frontier | color | 30 min. | | | | | | Modern: 3009 |
| 4-5 | Desalting the Seas | color | 17 min. | (*) | | | | | |
| 4-5 | Rocks that Form on the Earth's Surface | B&W<br>color | 16 min. | | | | 2199<br>2198 | | |
| 4-6 | Rocks that Originate Underground | B&W<br>color | 23 min. | | | | 2403<br>2402 | | |
| 4-6 | Volcanoes in Action | B&W | 11 min. | | | | 221 | | |
| 4-7 | Conquering the Sea | color | . . . | | | | | | Modern: 3013 |
| 4-7 | Prehistoric Times: the World Before Man | either | 11 min. | | | 717 | | | |
| 4-7 | Why Do We Still Have Mountains? | color | 11 min. | | | (*) | | | |
| 4-8 | Earthquake | either | 14 min. | | 16-148 | | | | |
| 4-9 | How We Study the Sun | color | 14½ min. | | 16-622 | | | | |

16 MM FILMS (cont)

| Where Used | Film Title | Color or B&W | Time | FILM SOURCE AND CATALOG NUMBER: Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|
| 4-9 | The Nearest Star | B&W<br>color | 27 min. | | | | | 681105<br>681118 | |
| 4-9 | The Sun | B&W | 29 min. | | | | | | N.E.T.: (*) |
| 4-9 | To the Moon | color | 30 min. | | | | | | Modern: (*) |
| 4-10 | Mars and Beyond | color | 30 min. | | | | | | Modern: 3006 |
| 4-10 | Space Science: Man-Made Satellites | either | 11 min. | | | 1648 | | | |
| 4-10 | Why Explore Space? | either | 19 min. | | | | | | Churchill: (*) |
| 4-11 | Fingerprints of the Stars | color | 12 min. | | (*) | | | | |
| 4-11 | Light and Color | color | 14 min. | | | | 1876 | | |
| 4-11 | Space Science: Studying the Stars | either | 13½ min. | | | 1644 | | | |
| 4-11 | Sound Waves and Stars | color | 12 min. | | 16-104 | | | | |
| 4-12 | The Earth in Space | B&W | 29 min. | | | | | | N.E.T.: (*) |
| 4-12 | The Earth's Movements | B&W | 11 min. | | | | 18102 | | |
| 4-12 | How We Know the Earth Moves | either | 11 min. | | 16-43 | | | | |
| 4-12 | Latitude, Longitude, and Time Zones | color | 25 min. | | | | | | N.A.S.A.: (*) |
| 4-12 | Solar Eclipse Expedition 1966 | color | 32 min. | (*) | | | | | |
| 4-12 | Why Seasons Change | either | 11 min. | | (*) | | | | |

16 MM FILMS (cont)

| | | | | FILM SOURCE AND CATALOG NUMBER | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Where Used | Film Title | Color or B&W | Time | Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
| 5-1 | Automation: What It Is and What It Does | either | 13½ min. | | | 1661 | | | |
| 5-1 | The Control Revolution | B&W | 29 min. | | | | | | Indiana Univ.: (*) |
| 5-2 | Learning About Heat | B&W | 8 min. | | | | 889 | | |
| 5-3 | Glass: from the Old to the New Through Research | B&W<br>color | 20 min. | | | | 777<br>766 | | |
| 5-3 | Synthetic Fibers– Nylon and Rayon | B&W | 14 min. | | | | 435 | | |
| 5-4 | Electricity from Chemicals | either | 13½ min. | | | 1659 | | | |
| 5-4 | Electricity: Measurement | either | 12 min. | | | | | | Indiana Univ.: (*) |
| 5-4 | Measurement of Electricity | either | 11 min. | | | 217 | | | |
| 5-5 | Electricity: Distribution | either | 15 min. | | | | | | Indiana Univ.: (*) |
| 5-5 | Electricity: How It Is Generated | either | 11 min. | | | 1301 | | | |
| 5-5 | Electricity: Production | B&W | 16 min. | | | | | | Indiana Univ.: (*) |
| 5-5 | Electricity: Principles of Safety | B&W | 11 min. | | | 1305 | | | |
| 5-5 | How to Produce Electric Current with Magnets | B&W<br>color | 11 min. | | | | 1883<br>1882 | | |
| 5-5 | My Pop's a Lineman | color | 16 min. | | | | | | I.F.B.: 21 FB 207 |
| 5-5 | Series and Parallel Circuits | B&W | 11 min. | | | | 259 | | |
| 5-5 | Superconducting Magnets | color | 12½ min. | (*) | | | | | |
| 5-6 | Magnetism and Electricity | B&W<br>color | 17 min. | | | | | 653210<br>653310 | |

| Where Used | Film Title | Color or B&W | Time | FILM SOURCE AND CATALOG NUMBER: Atomic Energy Comm. | Bailey Film Assoc. | Coronet Films | Encyclo. Britan. | McGraw-Hill | Miscellaneous |
|---|---|---|---|---|---|---|---|---|---|
| 5-7 | Airplanes: Principles of Flight | either | 11 min. | | | 1215 | | | |
| 5-7 | Boats: Buoyancy, Stability, Propulsion | either | 13½ min. | | | 1182 | | | |
| 5-7 | Broken Glass | color | 13 min. | | | | | | I.F.B.: 2CAL57 |
| 5-7 | Fatal Meeting | color | 16 min. | | | | | | I.F.B.: 2 CAL55 |
| 5-7 | Laws of Motion | B&W | 13 min. | | | | 751<br>576 | | |
| 5-7 | Where Mileage Begins | color | 26 min. | | | | | | General Motors: (*) |
| 5-8 | Your Voice and the Telephone | color | 7 min. | | | | | | Bell Telephone: 59900 |
| 5-9 | Fundamentals of Acoustics (2nd ed.) | B&W | 11 min. | | | | 478 | | |
| 5-9 | Sounds All About Us | either | 11 min. | | | 805 | | | |
| 5-9 | Sound Waves and Their Sources (2nd ed.) | B&W | 11 min. | | | | 477 | | |
| 5-10 | Development of Communications (2nd ed.) | B&W | 10 min. | | | | 884 | | |
| 5-10 | Girdle Round the Earth | B&W | 20 min. | | | | | | I.F.B.: 21FB396 |
| 5-10 | Television: How it Works | either | 11 min. | | | 647 | | | |
| 5-11 | Experiments in Controlling Brush Fires with Detergent Foam | color | 6½ min. | (*) | | | | | |
| 5-11 | Fire, Cause for Alarm | color | 12½ min. | | | | | | Bell Telephone: 63000 |
| 5-11 | Fire Prevention in the Home (2nd ed.) | B&W<br>color | 11 min. | | | | 2419<br>2418 | | |
| 5-11 | Time Out for Trouble | B&W | 22 min. | | | | | | I.F.B.: 2M56 |
| 5-11 | A Way with Fires | B&W | 30 min. | | | | | | Bell Telephone: 40,000 |

## FILMLOOPS

| Where Used | Filmloop Title | 8mm or Super 8 | Color or B&W | Length | FILMLOOP SOURCE AND CATALOG NUMBER: Ealing | Encyclo. Britan. | Wards |
|---|---|---|---|---|---|---|---|
| 1-1 | Shapes | either | color | | | 80780[1] | |
| 2-1 | Archimedes' Principle | Super 8 | color | 2½ min. | 82-0027 | | |
| 2-2 | Density of Liquids | Super 8 | color | 2½ min. | 82-0043/1 | | |
| 2-2 | Identifying Solids by Density | Super 8 | color | 4 min. | 80-3262/1 | | |
| 2-2 | Identifying Liquids by Density | Super 8 | color | 4 min. | 80-3270/1 | | |
| 2-2 | Identifying Gases by Density | Super 8 | color | 4 min. | 80-3288/1 | | |
| 2-5 | Conservation of Mass | Super 8 | color | 4 min. | 80-3254/1 | | |
| 2-6 | Diffusion | Super 8 | color | 3 min. | 80-2959/1 | | |
| 2-7 | Combining Volumes: Synthesis of Water | Super 8 | color | 3 min. | 84-0173/1 | | |
| 2-8 | Definite Proportions: Electrolysis of Water | Super 8 | color | 3½ min. | 84-0165/1 | | |
| 2-10 | Radioactivity | Super 8 | color | 3-1/3 min. | 80-3346/1 | | |
| 2-10 | Introduction to Electrostatics | Super 8 | color | 3½ min. | 80-2819/1 | | |
| 2-10 | Radioactive Decay | Super 8 | color | 5 min. | 80-2009/1 | | |
| 3-3 | Simple Machines: | | | | | | |
| | Action of the Lever I | either | color | 3 min. | | 80824[1] | |
| | Action of the Lever II | either | color | 3 min. | | 80825[1] | |
| | Action of the Lever III | either | color | 3 min. | | 80826[1] | |
| | The Pulley I | either | color | 3 min. | | 80828[1] | |
| | The Pulley II | either | color | 3 min. | | 80829[1] | |
| | The Gear | either | color | 4 min. | | 80831[1] | |
| | The Wheel and Axle | either | color | 4 min. | | 80833[1] | |

(1) Prefix catalog number with R for Regular 8 mm, and with S for Super 8

| Where Used | Filmloop Title | 8mm or Super 8 | Color or B&W | Length | Ealing | Encyclo. Britan. | Wards 8 mm | Wards Super 8 |
|---|---|---|---|---|---|---|---|---|
| 3-4 | Simple Machines: | | | | | | | |
| | The Inclined Plane | either | color | 4 min. | | 80827[1] | | |
| | The Screw | either | color | 3 min. | | 80830[1] | | |
| | The Wedge | either | color | 3 min. | | 80832[1] | | |
| 4-2 | Air Expansion by Heat | either | color | 3½ min. | | 80742[1] | | |
| 4-3 | Condensation of Water Vapor | either | color | 3½ min. | | 80736[1] | | |
| 4-4 | Stream Table Film Loop Series | | | | | | 8 mm | Super 8 |
| | a. Mass Wasting: Dry | either | color | | | | 74W1004 | 74W1024 |
| | b. Mass Wasting: Moist | either | color | | | | 74W1005 | 74W1025 |
| | c. Stream Erosion Cycle | either | color | | | | 74W1009 | 74W1029 |
| | d. Waterfalls | either | color | | | | 74W1012 | 74W1032 |
| 4-5 | Allurial Fan and Lake Delta | Super 8 | color | 3 min. | 85-0040/1 | | | |
| 4-5 | Sedimentation | either | color | 3½ min. | | 80106[1] | | |
| 4-5 | Sediment Deposition | either | color | 3 min. | | 80743[1] | | |
| 4-5 | Stream Table Film Loop Series | | | | | | 8 mm | Super 8 |
| | Sedimentation, Turbidity Currents | either | color | | | | 74W1006 | 74W1026 |
| | Sedimentation, Settling Rate | either | color | | | | 74W1007 | 74W1027 |
| 4-7 | Stream Table Film Loop Series | | | | | | 8 mm | Super 8 |
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| 4-7 | Volcanism | Super 8 | color | 2-3/4 min. | 85-0156/1 | | | |
| 4-9 | Lunar Eclipses | either | color | 3½ min. | | 81150[1] | | |
| 4-9 | Solar Eclipse | either | color | 3 min. | | 81149[1] | | |
| 5-7 | Archimedes' Principle | Super 8 | color | 2½ min. | 82-0027/1 | | | |
| 5-7 | The Buoyant Force | Super 8 | color | 3½ min. | 82-0019/1 | | | |

(1) Prefix catalog number with R for Regular 8 mm, and with S for Super 8

## FILMSTRIPS

| Where Used | Filmstrip Title | Color or B&W | Number of Frames | Encyclo. Britan | Popular Science Publish. | Society Visual Ed. | Other |
|---|---|---|---|---|---|---|---|
| | | | | FILMSTRIP SOURCE AND CATALOG NUMBER | | | |
| 1-6 | Measurements Are for a Purpose | | | | | | (Note that a 14 minute record goes with each Part: Cat. No. 562-IRR) |
| | Part I: Standards and Measurement | color | 54 | | | 562-1 | |
| | Part II: Measurement Systems & Theory | color | 52 | | | 562 | |
| 1-7 | Experiments With Length | color | 41 | | | 449-1 | |
| 1-7 | The Metric System | B&W | 40 | | | | McGraw-Hill: 643010 |
| 1-9 | Graphs: Pictographs, Bar, Line, Number Pairs, Maps | color | 47 | | | 532-11 | |
| 2-10 | Man Discovers the Atom | color | 49 | 8860 | | | |
| 3-4 | Simple Machines Make Work Easier | color | 40 | | 554 | | |
| 3-5 | What Makes Engines Go | color | 40 | | 12D | | |
| 3-5 | Heat and Work–Engines | color | 40 | | 646 | | |
| 3-9 | Using Atomic Energy for Electric Power | color | 40 | | 568 | | |
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| 4-8 | Exploring for Oil | color | . . . | | | | Heath: 8A-6, 09159 |
| 4-10 | Scientific Measurement–Molecules to Stars | color | 40 | | 588 | | |
| 5-10 | How Color Television Works | color | 40 | | 545 | | |

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| Where Used | Transparency Title | Transparency Source and Catalog Number: School Products Company | Other |
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| 1-7 | Metric Units | 8300 | |
| 1-9 | Graphs and Analysis of Data | Ph-6.00 | |
| 3-1 | Force + Distance = Work | Sc-8264 | |
| 3-1 | Transferring Force | Sc-8272 | |
| 3-5 | Reciprocating Engine | Sc-8274 | |
| 3-5 | Steam Engine | Sc-8275 | |
| 3-5 | Internal Combustion Engine | Sc-8276 | |
| 3-7 | Nuclear Powered Steam Turbine Generator | | Univ. Ed.: UT 1609 |
| 4-1 | Weather Information Map | Sc-8394 | |
| 4-3 | Water Cycle | Sc-8398 | |
| 4-12 | The Earth | | Popular Science Publishing Co.: Set TEV-1 |
| 5-8 | Telegraph Circuit | Sc-8351 | |
| 5-8 | Telephone Handset | Sc-8352 | |
| 5-10 | Color Television Tube | Sc-8259 | |

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